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Capture and On-Site Release of Nuisance Black Bears and Survival of Orphaned Black Bears Released in The Great Smoky Mountains

Jay Edwin Clark
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To the Graduate Council:

I am submitting herewith a thesis written by Jay Edwin Clark entitled "Capture and On-Site Release of Nuisance Black Bears and Survival of Orphaned Black Bears Released in The Great Smoky Mountains." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Wildlife and Fisheries Science.

Michael R. Pelton, Major Professor

We have read this thesis and recommend its acceptance:

Frank van Manen, Joe Clark, Arnold M. Saxton

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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CAPTURE AND ON-SITE RELEASE OF NUISANCE BLACK BEARS AND SURVIVAL OF ORPHANED BLACK BEARS RELEASED IN THE GREAT SMOKY MOUNTAINS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee

Jay Edwin Clark

August 1999

DEDICATION

This thesis is dedicated to my parents, Jonathan and Barbara Clark, for their unending love, prayers, and guidance throughout my life. Without their support, this thesis and my dreams would not have been possible.

Thanks Mom and Dad!

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ABSTRACT

Since the establishment of Great Smoky Mountains National Park (GSMNP) in 1934, interactions between black bears (*Ursus americanus*) and visitors have been a regular occurrence. Prior to 1990, capture and relocation was the primary management alternative for nuisance bears in GSMNP. Since 1990, wildlife biologists in GSMNP have used capture and on-site release as an aversive conditioning technique for nuisance black bears. This technique involves capturing and immobilizing bears that frequent developed areas, collecting biological data, and releasing the bears back into the same area. The premise of this technique is to reinforce the natural fear of humans and thereby reduce the likelihood of return. Although capture and on-site release seems to have had some success in deterring nuisance bears from developed areas of GSMNP, it has not been tested quantitatively.

I evaluated capture and on-site release as a management technique for nuisance black bears in GSMNP. The objectives of Part 1 of my study were to identify correlates of success for on-site releases, estimate survival, and evaluate movements in relation to the release sites of nuisance black bears.

During 1997 and 1998, I captured and released 28 bears (16 males, 12 females) a total of 30 times. Bears were released in picnic areas ($n = 14$), backcountry campsites or shelters ($n = 10$), campgrounds ($n = 2$), parking lots ($n = 1$), and roadsides ($n = 1$). Nine of the 28 bears (32%) were relocated to different areas as a result of continued nuisance activity

I defined the overall success rate of on-site releases as the total number of bears that were not relocated within the same year divided by the total number of bears released on-site. Between 1990-1998, 63 bears (44 males, 13 females, and 11 females with young) were released on-site in frontcountry areas of GSMNP a total of 85 times with an overall success rate of 74%.

I used data from 1990-1998 to identify the key factors that contribute to the success of on-site releases in frontcountry areas of GSMNP. I developed multiple variable logistic regression models based on 6 different success definitions to identify correlates of success. Success definitions were defined by post release observations or management actions at the release site within the same year and in successive years. My analysis identified sex, family group size, capture area type, time of nuisance activity, and population abundance as important variables in determining success of on-site releases. The results indicated that success of on-site releases may be increased by frequent night-time monitoring of campgrounds and picnic areas to detect and capture nuisance bears when they are night active and coordinating the frequency and effort of monitoring based on the estimated population increase or decrease from the previous year. Managers in GSMNP can use these models to predict and compare the relative probability of management success for various scenarios.

During 1997-1998, I radio-collared and monitored 23 bears (12 males, 11 females) to estimate survival of bears released on-site. I estimated survival using the Kaplan-Meier staggered entry procedure. Survival during the entire study period for all bears was 0.71 (95% CI = 0.50-0.93). Survival for males and females during the study was 0.50 (95% CI = 0.24-0.76) and 1.00 (95% CI = 0.76-1.00), respectively. Although survival functions between the sexes did not differ ($P = 0.22$), overall survival rates were different ($P < 0.001$). Legal hunting was the only cause of mortality during the study.

I used compositional analysis to determine bear movements in relation to their release sites. I used telemetry data from 14 bears (9 males, 5 females) to calculate home ranges and created distance zones of 1, 2, 3, 4, 5, and >5 km around each release site. The distance zone >5 km from the release site had the highest proportional composition for home range area and the number of locations within each zone. However, bear use between the distance zones did not differ suggesting that bears were neither avoiding nor attracted to the area of the release sites. Thus, on-site releases did not displace bears from the area near the release sites.

The results from my study indicated that capture and release on-site is a viable management alternative to relocation and better meets the objective for bear management in GSMNP. Capture and release on-site requires biologists to take a proactive approach to managing nuisance bears and allows bears to remain in GSMNP as a continued resource.

Rehabilitation and release of orphaned bears into the wild offers a management alternative for black bear managers. The objective of Part II of my study was to estimate survival of orphaned bears that were rehabilitated and released into the Great Smoky Mountains. Between October 1997 and June 1998, I released 11 rehabilitated orphan bears (6 males, 5 females) into the Smoky Mountains. I monitored released bears via radio telemetry from January 1998 to October 1998. I documented no mortality during the study period. I estimated survival using the Kaplan-Meier staggered entry procedure and backdated release dates to determine survival of bears by postrelease days. Because

the fate of 2 bears in the study was unknown, I performed 2 analyses to estimate minimum and maximum survival. Survival up to 180 days postrelease ranged from 0.77 (90% CI = 0.34-1.00) to 1.00 (90% CI = 0.76-1.00). The results indicated that short-term survival (up to 180 days) of rehabilitated orphan bears is possible may be a viable alternative to managers for dealing with orphan bears.

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CHAPTER 1

INTRODUCTION

Bear Behavior

The omnivorous food habits and opportunistic behavior of bears (*Ursus* spp.) contribute to negative interactions between humans and bears. Black bears are highly mobile, curious, intelligent, and adaptable animals (Pelton 1982) that will exploit human-related food sources when given the opportunity. These unnatural sources of food initiate behavioral changes in wild bears that may lead to food conditioning or habituation to humans (McCullough 1982, Herrero 1985, Gilbert 1989).

Habituation is the loss of fear of humans through lack of negative reinforcement (McCullough 1982). Food conditioning is a form of habituation where a bear forms an association between people and food (Herrero 1985). Food conditioning of bears frequently results in property damage, threats to human safety, and destruction or relocation of nuisance animals (Singer and Bratton 1980, Herrero and Fleck 1990). Although food conditioning almost always involves some habituation to the smell or sight of humans (Herrero 1985), habituation can occur independent of food conditioning where bears and humans come into frequent, harmless contact (McCullough 1982). For example, grizzly bears (*Ursus arctos*) at McNeil River Falls in Alaska are habituated to human presence but not conditioned to human foods. This relationship between bears and humans can exist because the process of bear habituation to people can be controlled by limiting the number of visitors, strict regulations and enforcement on visitor use, and eliminating the availability of human food and garbage to bears (Herrero 1985).

Black Bear Management in Great Smoky Mountains National Park

Since establishment of Great Smoky Mountains National Park (GSMNP or Park) in 1934, interactions between black bears and visitors have been a regular occurrence (Pelton et al. 1976, Singer and Bratton 1980, Tate and Pelton 1983, Hastings et al. 1987, McLean and Pelton 1990). The availability of human food and garbage to bears (Pelton 1975, Singer and Bratton 1980) and the naivete of visitors regarding bear biology and behavior (Burghardt et al. 1972, Pelton et al. 1976, Tate and Pelton 1983, Petko-Seus and Pelton 1984) have substantially contributed to nuisance bear activity. Although many changes have been implemented to decrease the availability of human foods and garbage to bears (e.g., bear-proof garbage cans, dumpsters, and backcountry cable systems) and to increase visitor knowledge of bear behavior (DeLozier and Stiver 1996), bear problems still persist in many areas of GSMNP.

The objective of black bear management in GSMNP is to guide the management of visitors, concessionaires, employees, and bears in a manner that allows bears to live naturally, yet still provide for safe visitor use (DeLozier 1993). Because of a variety of factors, including the violation of National Park Service (NPS) regulations regarding food and bears (Pelton 1975, Singer and Bratton 1980), a high visitor density (Singer and Bratton 1980), a high bear density (Coley 1995), and habitat conditions (Harms 1979), habituation of bears to humans in GSMNP is not tolerated.

Reactive Management. Prior to 1990, capture and relocation was the primary management alternative for nuisance bears in GSMNP (Stiver 1991). Traditionally, bears in GSMNP were not considered nuisance animals until they habitually entered campgrounds or appeared along roadsides and caused injury to visitors or property damage (Beeman and Pelton 1976). Once a bear exhibited this behavior, it was relocated. Thus, management actions by GSMNP biologists were "reactive" because nuisance bears were dealt with after they had already habituated to humans and nuisance activity.

Many studies have evaluated relocation as a management technique for nuisance black bears (Beeman and Pelton 1976, McArthur 1981, Fies et al. 1986, Rogers 1986*a*, Stiver 1991, Comly 1993). Bears possess a keen homing ability (Beeman and Pelton 1976, Rogers 1986*b*) and relocations of bears tend to have limited success (Stiver 1991). Relocation also may result in increased mortality and decreased survival (Fies et al. 1986, Rogers 1986*a*, Stiver 1991, Comly 1993, Riley et al. 1994, Blanchard and Knight 1995). Relocation may affect the social structure of both the local population from which bears were removed and the population into which they were released. Relocation of adult males may precipitate increased nuisance activity as a result of an influx of sub-adult males from other areas (Tate and Pelton 1983). In addition, the relatively poor success and high mortality of relocated bears may erode the credibility of a management program (Riley et al. 1994).

Beeman and Pelton (1976) identified potential problems specifically associated with relocation in GSMNP. First, the area of GSMNP (approximately 32 km by 70 km) may not be large enough to successfully transplant bears captured in some areas. Studies have shown that success rates for relocation are increased when relocation distance is >64 km from capture site (Fies et al. 1986, Rogers 1986*a*, Stiver 1991); therefore, relocation of a nuisance bear >64 km within GSMNP is not possible in many cases. The limited road system within in the Park also hinders moving bears to remote areas. Finally, the lack of a buffer between the Park and the dense human population density surrounding GSMNP may increase a bear's vulnerability to mortality factors (e.g., legal and illegal hunting).

General Problem Statement

Proactive Management. Substantial amounts of money, time, and effort are required to relocate nuisance bears (Beeman and Pelton 1976, McArthur 1981, Riley et al. 1994). The negative impacts and low success rate associated with relocating nuisance black bears, and a decreased interest in receiving transplanted bears by state wildlife agencies (i.e., North Carolina and Tennessee), have led wildlife biologists in GSMNP to change from a reactive approach of management (i.e., relocation) to a more aggressive, "proactive" program. This proactive approach to management is aimed at the prevention of nuisance activity and behavioral modification of nuisance black bears.

Capture and On-site Release. Since 1990, wildlife biologists in GSMNP have used capture and on-site release as the primary management technique for nuisance black bears (Brady and Maehr 1982, Wooding et al. 1989, Shull 1994). This technique is a form of aversive conditioning that involves capturing and immobilizing a bear that frequents a developed area, collecting biological data, and releasing the bear into the same area. Aversive conditioning involves a negative reinforcer which is presented to a bear engaged in an undesirable behavior (Gillin et al. 1994). The process of being captured and handled by humans is the aversive stimulus involved in capture and on-site release. Although the procedure is harmless to the bear, it possibly reinforces the natural fear of humans in a bear causing it to avoid the developed area where capture occurred.

Little information is available on capture and on-site release as a management technique for nuisance black bears. Brady and Maehr (1982) evaluated the success of capture and release on-site with apiary-raiding black bears in Florida. They documented 8 of 9 nuisance bears being successfully deterred from the area of capture with this technique. Wooding et al. (1988) evaluated capture and on-site release with apiary-raiding black bears in Florida and had a success rate (no relocation necessary after on-site release) of 86% for 63 tagged bears. Three of these bears were radio collared and remained in the area of the release site but were never recaptured. Shull (1994) evaluated the success of on-site releases of nuisance male bears in Arkansas and documented no further problems at the initial capture site for 12 of 15 bears. Other studies, not specifically evaluating capture and on-site release of nuisance bears, have reported behavior modification of bears after being released at the capture site (Amstrup and Beecham 1976, Gillin et al. 1994, Chi et al. 1998).

Although preliminary observations indicated some success in deterring nuisance bears from developed areas of GSMNP, capture and on-site release as a management technique has not been tested quantitatively. As with other aversive techniques, the behavioral response of a bear to being captured and released on-site may depend on a variety of factors including the level of habituation to humans, level of food conditioning, sex and age of the bear, breeding status, physical condition, status of the local population, and natural food availability (Gillin et al. 1994). Furthermore, information related to survival and movements of bears released on-site is lacking and may influence the effectiveness of the technique.

This study evaluated capture and on-site release as a management technique for nuisance black bears in GSMNP. The objectives of the study were to: (1) identify correlates of success for on-site releases of nuisance black bears in GSMNP, (2) estimate survival of released black bears, and (3) evaluate movements in relation to the release sites of nuisance black bears.

CHAPTER II

STUDY AREA

GSMNP encompasses 208,000 ha on the Tennessee and North Carolina border (Figure 1). The area includes portions of Blount, Sevier, and Cocke counties in Tennessee and Haywood and Swain counties in North Carolina. The Park is partially surrounded by Cherokee National Forest in Tennessee and Nantahala and Pisgah national forests in North Carolina. Most of the Tennessee portion of GSMNP is bordered by private land, much of which is developed. The Cherokee Indian Reservation borders the Southeast portion of GSMNP.

Topography

The Great Smoky Mountains lie in the southern division of the Appalachian Highlands and are part of the Unaka Mountain Range of the Blue Ridge Province (Fenneman 1938). The area is characterized by mountainous terrain with prominent peaks and finger ridges radiating from the main crest. The main crest is oriented northeast to southwest and connects the highest peaks within GSMNP for 113 km (Golden 1974). Elevations range from 270 m at the mouth of Abrams Creek to 2,024 m at Clingmans Dome, the second highest peak in the eastern United States. Bedrock within the study area consists of sandstones of the Ocoee series formed during the Precambrian Era. Major components of the parent material are quartz, feldspar and slate with small percentages of schist and limestone (King et al. 1968). Soils are of the

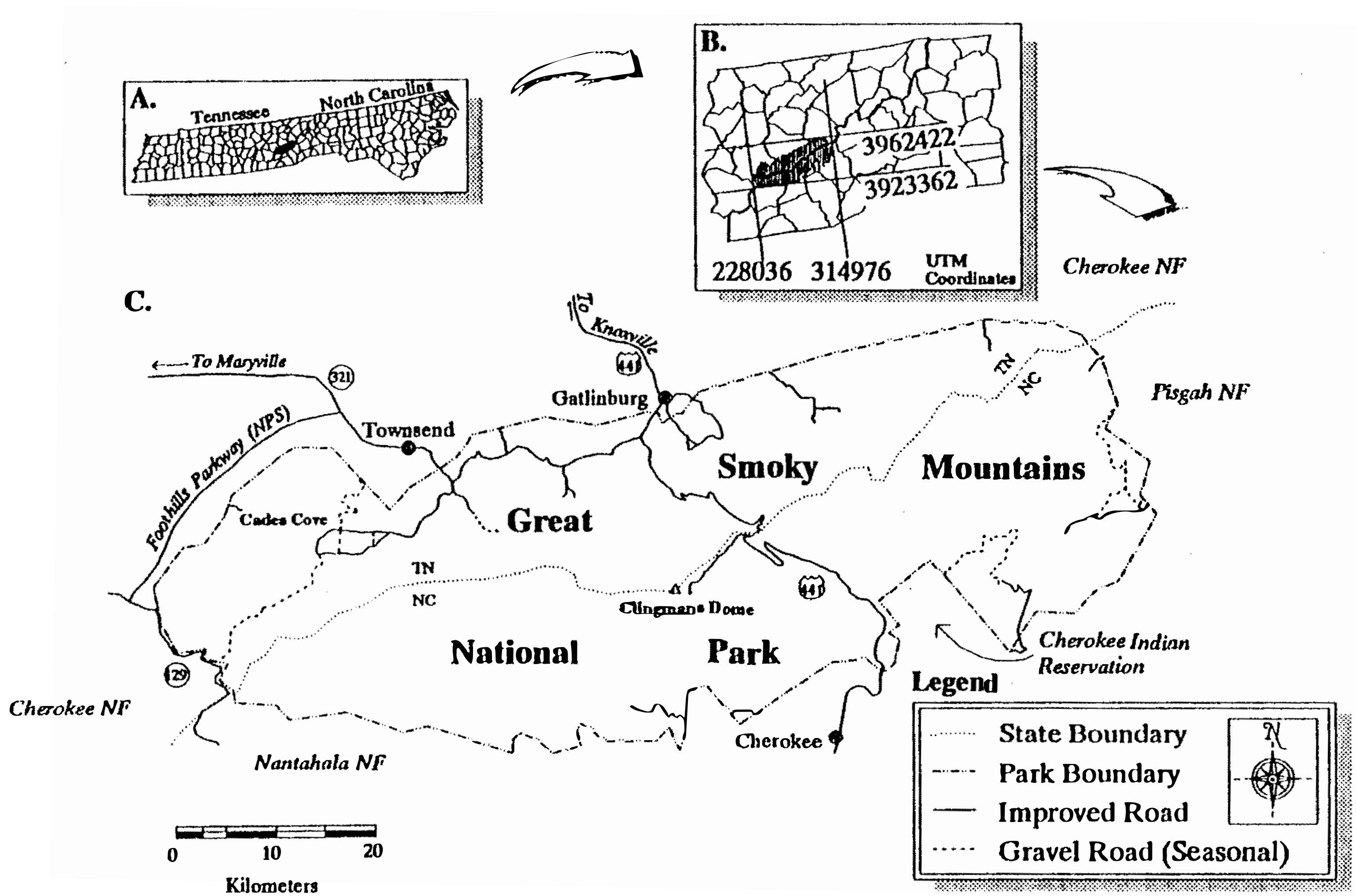


Figure 1. Great Smoky Mountains National Park. A. General location. B. Detail of general location with Universial Transverse Mercator coordinates of boundaries. C. Detail of national park (adapted from van Manen 1994).

Ramsey association characterized by low water storage capacity, moderate fertility, and medium to high acidity (Soil Survey 1953).

Climate

Variation in elevation, aspect, and slope creates varied microclimate conditions within GSMNP (Shanks 1954, Stephens 1969). Thornthwaite (1948) classified the climate of the area as warm-temperate rain forest (mesothermal per-humid). Average annual precipitation ranges from 140 cm at lower elevations to 230 cm at higher elevations (Stephens 1969). Snow accumulation during the winter is slight, with the mean annual number of days with snowfall ranging from approximately 7 at lower elevations to almost 26 at the highest elevations (Shanks 1954). Annual temperatures range from 8° C at higher elevations to 14° C at lower elevations. The temperature gradient is 4° C per 1,000 m change in elevation (Shanks 1954).

Flora and Fauna

The variation in elevation, precipitation, and temperature creates a great diversity of flora and fauna in GSMNP. Stupka (1960) reported over 1,300 flowering plants including 130 species of trees. Over 2,000 fungi, 330 mosses, 230 lichens, and 32 fern species have been identified in GSMNP (King and Stupka 1950, Stupka 1960). Linzey and Linzey (1971) described 59 species of mammals in GSMNP. Over 200 species of birds, 30 species of reptiles, 39 species of amphibians, 80 species of fish, and a great variety of insects and other invertebrates have been recorded in the Park (King and Stupka 1950).

Human Activities

Prior to its establishment in 1934, about 63% of GSMNP was logged, settled, or disturbed by humans (Pyle 1988). Today, GSMNP is the most visited national park in the country with greater than 9 million visits per year. Developed areas include 10 developed campgrounds, 9 picnic areas, 99 backcountry campsites, and 16 backcountry shelters. Popular visitor activities include hiking, camping, picnicking, horseback riding, bicycling, kayaking, tubing, and wildlife viewing. In 1998, 92,522 and 357,623 users were recorded at backcountry campsites and developed campgrounds, respectively.

Black Bears

Settlement during the early 1800's probably had only a marginal effect on black bear populations in GSMNP. However, because of excessive logging, hunting, and trapping in the late 1800's and 1900's, the black bear population declined dramatically and was mostly restricted to higher elevations and inaccessible areas (LaFollette 1974). After the establishment of the Park, bear populations seemed to increase as a result of national park protection. The bear population may have experienced another population decline during the 1940's because of the loss of the American chessnut (*Castenea dentata*) and several hard mast failures (LaFollette 1974). Since the start of population monitoring by the University of Tennessee in 1968, the black bear population has gradually increased (McLean 1991) and was estimated between 1,000 and 2,200 individuals during the summer of 1998 (T. Eason, Univ. of Tennessee, personal communication).

As a result of a high-density black bear population and high human visitation, human-bear incidents are a regular occurrence (LaFolette 1974, Stiver 1991). Between 1990 and 1998, 1,414 nuisance bear incidents were recorded in GSMNP (Table 1). Of these, 516 incidents involved property damage resulting in an estimated cost $39,069, and 18 incidents involved human injuries (Table 1). Hunting is prohibited within the Park but occurs on adjacent lands. The primary source of reported human-related mortality within GSMNP is vehicle collisions.

Table 1. Summary of nuisance black bear incidents in Great Smoky Mountains National Park, 1990-98.

Year	No. of Incidents	No. of Damage Incidents	Estimated Property Damage (U.S. $)	No. of Human Injuries
1990	71	71	7,118	7
1991	159	75	8,087	0
1992	185	59	5,678	2
1993	111	36	3,550	0
1994	166	60	3,386	1
1995	212	46	4,561	3
1996	188	52	2,685	3
1997	212	85	3,359	1
1998	110	28	645	1
Total	**1,414**	**516**	**39,069**	**18**

CHAPTER III

METHODS

Capture and Handling

I monitored human use areas in GSMNP for nuisance bear activity from May 1997 – December 1998. I classified human use areas as either frontcountry or backcountry areas. I defined frontcountry areas (i.e., picnic areas, roadsides, and campgrounds) as areas accessible to the public by automobiles. Backcountry areas (i.e., campsites) were defined as areas accessible by foot only. I monitored frontcountry areas for bear activity by spotlighting, visual observations, and visitor reports. I primarily relied on visitor reports to monitor backcountry areas. When bear activity was detected in a human use area, behavior of the bear, time of activity, and visitor use at time of activity were recorded. I attempted to capture offending individuals as soon as possible after initial observation was reported.

Bears were captured using aluminum culvert traps, spring-activated Aldrich foot snares (Johnson and Pelton 1980), or CO_2 pistol. Traps were baited with sardines, donuts, bacon, or other human foods. I immobilized bears with a mixture of ketamine hydrochloride (Ketaset, Burns Veterinary Supply, Inc., Farmers Branch, Texas) (200 mg/ml), xylazine hydrochloride (Rompun, Haver-Lockhart, Inc., Shawnee, Kansas) (100mg/ml), and mepivicaine hydrochloride (Carbocaine V, Winthrop Lab., New York, N.Y.) (20 mg/ml) injected intramuscularly (Cook 1984) at a dosage rate of 1ml/110 kg estimated body weight. A wetting agent (Artificial Tears, Maurry Biol. Co., Los Angeles, Calif.) was applied to the eyes of each bear after immobilization occurred to prevent desiccation. I ear-tagged both ears and tattooed each bear on the upper lip and flank of the groin area (Johnson and Pelton 1980). A first premolar was extracted, sectioned, and stained (Eagle and Pelton 1978) for aging by counting cementum-annuli (Willey 1974). Reproductive status and morphometric measurements were recorded. I fitted each bear with a Telonics MOD-500 radio transmitter equipped with activity and mortality tip-sensors (Telonics Inc., Mesa, Arizona). Yohimbine (Lloyd laboratories, Shenandoah, Iowa) was administered intravenously as an antagonist for xylazine hydrochloride when handling was completed.

Bears were released < 150 m from the capture location. After release, I used radio telemetry, visitor reports, and spotlighting to monitor the release site for continued nuisance behavior. When a bear was observed at its release location, the bear was hazed by chasing, noise deterrents, or rubber bullets. In some cases, offending bears were captured and released on-site a second time. If a bear progressed to day activity in a frontcountry area, it was usually recaptured and relocated.

Capture and On-site Release

I used capture data (1990-98) to calculate the success rate of bears released on-site in GSMNP. Success rate was defined as the number of bears that were released on-site that did not have be relocated within the same year divided by the total number of bears released on-site. Success rate in this study was based on the definition for success in previous studies pertaining to capture and release on-site (Brady and Maehr 1982, Wooding et al. 1989, Shull 1994).

Model Development. I used 3 variables (Table 2) to classify each on-site release as a success or failure according to 6 different definitions of success (Table 3). I excluded observations that did not meet the definition for either success or failure. Success or failure was used as the dependent variable in a logistic regression model (Hosmer and Lemeshow 1989). The independent variable in logistic regression is binomial and can be categorical or continuous. Logistic regression requires few assumptions and is not dependent on an assumption of multivariate normality (Hosmer and Lemeshow 1989). Because some bears were released on-site more than once, I tested whether previous releases affected success of capture and release on-site. I used 9 independent variables to determine correlates of success (Table 4).

Model Selection. For each definition of success (Table 3), I performed univariate logistic regression to evaluate the effect of each independent variable. I excluded all variables with a P-value >0.50 from further analysis in order to reduce the number of variables for the best model selection. I used multivariable stepwise logistic regression as a model selection procedure where a P-value < 0.50 was required for entry in the model and a P-value < 0.10 was required for staying in the model.

Model Validation. Model validity allows for determination of confidence levels of model predictions and use for management decisions (Marcot et al. 1983). I tested each model with a jackknife procedure using Proc Logistic (SAS Institute, Inc. 1990). This procedure classifies an observation from the data set as a success or failure by removing the observation to be classified from the data and re-estimating the parameters of the model. From this, I obtained overall correct classification rates, sensitivity

Table 2. Variables to define success of black bears captured and on-site released in Great Smoky Mountains National Park, 1990-98.

Variable	Units/Categories	Explanation
Bear ID		3 or 4-digit ID number
Date	Month/Day/Year	Date of on-site release
Fate of Bear	1) Unknown/free ranging 2) Relocated from release site 3) Relocated from site different than release site 4) Captured and released on-site from initial release site 5) Captured and released on-site from site different than initial release site 6) Caused problems at the release site but never recaptured 7) Roadkill 8) Hunter kill 9) Caused problems at site other than release site but not recaptured	Fate of bear after initial capture and on-site release

Table 3. Definitions for analyzing success of capture and on-site release for nuisance black bears in Great Smoky Mountains National Park, 1990-98.

Success Criterion #	**Explanation**
1	Success: No observations at the release location within the same year as on-site release
2	Success: No management action necessary at the release location within the same year as on-site release
3	Success: Relocation from release site not necessary within the same year as on-site release
4	Success: No observations at the release location in successive years
5	Success: No management action necessary at the release location in successive years
6	Success: Relocation from release site not necessary in successive years

Table 4. Independent variables to determine correlates of success for black bears captured and on-site released in Great Smoky Mountains National Park, 1990-98.

Variable	Units/Categories	Explanation
Previous on-site releases within the same year	No. of on-site releases	Total number of previous on-site releases within the same year
Previous on-site releases in years prior	No. of on-site releases	Total number of previous on-site releases in years prior to current release on-site
Sex/family group size	1) Male 2) Female 3) Female with young	
Age	Age in years	Ages obtained from cementum annuli
Release season	1) Fall/Winter 2) Spring 3) Summer	September, October, November, December, January, February March, April, May June, July, August
Time of nuisance activity	1) Day (sunrise – sunset) 2) Crepuscular (sunset - dark) 3) Night (dark – sunrise)	Time that bear was initially observed in a developed area
Capture area	1) Campground 2) Picnic area 3) Other	Type of developed area in which capture and release occurred
Population estimate	Count	Annual abundance estimate from UT trapping data for the Tennessee study area
Behavior	1) Passive/shy 2) Beggar/food conditioned/ aggressive/bold	Behavior of bear at time of capture
Total Oak		Indices for all oak species from the annual hard mast survey for GSMNP (NPS data)

(proportion of successes predicted to be successes), specificity (proportion of failures predicted to be failures), false positive rate (proportion of predicted successes that were failures), false negative rate (proportion of predicted failures that were successes), and reliability (Marcot et al. 1983). Reliability was defined as the fraction of model predictions that were empirically correct (sensitivity + specificity)/(sensitivity + specificity + false positive rate + false negative rate).

From the predicted probabilities, I determined the cut-off point for each model to classify observations as successes or failures by a high overall classification rate, a balance between sensitivity and specificity, and a low false positive rate (<25%) (Hassler et al. 1986). Although determination of the cut-off point using the above criteria may result in a greater probability of classifying successful releases as failures, it provides a conservative approach for making management decisions. Thus, a bear that was released on-site and predicted to be successful was allowed a 25% probability of failure.

Model Application. The relative probability of success for an on-site release can be predicted based on the logistic regression equation for each of the 6 models (Hosmer and Lemeshow 1989):

$$p = \frac{e^{g(x)}}{1 + e^{g(x)}}$$

where *g(x)* is the logit transformation, consisting of the sum of parameter estimates for nominal variables and the estimates of continuous parameters times their observed values. Thus, based on the variables associated with a certain definition of success, this value represented the relative probability that the on-site release would be successful.

The parameter estimates of the multiple variable logistic regression models were used to interpret the influence of the variables on success. For categorical variables, an odds ratio was calculated using the exponential difference in the parameter estimates ($e^{b_A - b_B}$). The odds ratio approximates how likely it was for an on-site release to be successful among observations with release variable class A versus variable class B. For example, if the parameter estimate was higher for females than males, the odds ratio for the variable sex would approximate the likelihood of an on-site release being more successful with a female versus a male. The odds ratios for continuous variables was dependent upon a defined change in the variable ($e^{b(x_1 - x_2)}$).

Telemetry

I monitored radio-collared bears using ground and aerial telemetry. Telemetry was performed using a Telonics TR-2 receiver (Telonics, Mesa, Arizona). I located radio-collared bears from a Cessna 172 or 182 with 2-element "H" antennas mounted on each wing strut and by ground triangulation with a hand-held, 2-element "H" antenna. Aerial locations were plotted on 7.5 minute United States Geological Survey (USGS) topographical maps and recorded as universal transverse mercator (UTM) coordinates. Ground locations were recorded using the loudest signal method (Springer 1979, Mech 1983). I recorded UTM coordinates for ground locations from 2 bearings using TELEM 88 (Koeln 1980). I used azimuths that were between 30-150 degrees and collected ≤ 30 minutes apart for analysis. Telemetry stations were set up at known locations that could be accurately determined on 7.5 minute USGS topographical maps.

Survival

I monitored radio-collared bears released on-site 1-3 times/2 weeks from May 1997 to December 1998 to estimate survival. Release date, first date monitored, last date monitored, sex, and fate were recorded for all radio-collared bears. Radio-collared bears that had to subsequently be relocated were censored by the relocation date. Mortality dates of radio-collared bears were recorded from 1997 and 1998 harvest data for North Carolina (North Carolina Wildlife Resources Commission, unpublished data) and Tennessee (Tennessee Wildlife Resources Agency, unpublished data).

I estimated survival over the entire study period, annually, and between sexes using the staggered entry Kaplan-Meier procedure (Pollock et al. 1989). Survival was estimated by

$$\hat{S}(t) = \prod_{\frac{j}{a_j} < t} \left(\frac{1 - d_j}{r_j} \right),$$

where $\hat{S}$ is estimated survival, a_j is a particular time of death, d_j is the number of bears that died at time a_j, r_j is the number of bears at risk at time a_j, , t is the time interval, and I am considering the product of all j terms for which $a_j <$ the time t. An estimate of variance (var) is:

$$\mathrm{var}\left[\hat{S}(t)\right] = \frac{[S(t)]^2[1 - S(t)]}{r(t)}.$$

Assumptions of the Kaplan-Meier procedure are: 1) bears monitored for survival were sampled randomly, 2) survival times were independent among bears, 3) capturing or radio collaring did not influence survival, 4) censoring mechanisms were random, and 5) newly radio-collared bears had the same survival function as previously radio-collared bears (Pollock et al. 1989).

I used the Log-rank test (Pollock et al. 1989) to compare survival functions between year and sex classes. I considered all tests significant at $P \leq 0.05$. Mortality was calculated for the study period as $1 - \hat{S}(t)$.

I recorded no mortalities during 1998 or for radio-collared females, therefore an estimate of variance and 95% confidence intervals could not be calculated given the formula provided by Pollock et al. (1989). An alternate method was used to calculate the lower 95% confidence intervals that considers the distribution of the number of bears that die annually, where the probability of a bear dying at time x equals $P_x(x, 0 - b)$ (b = number of bears) (Martorello 1998). Therefore, the probability of a bear released on-site dying equals $P_{(x=0)}$. By setting $\alpha = 0.05$, we have

$$P_{(x=0)} = P_L{}^{b} = 0.05,$$

where $P_L{}^{n}$ equals the probability that n bears live and solving for P_L as:

$$b \; ln \, P_L = ln \; 0.05$$

$$ln \, P_L = (ln \; 0.05) \, / \, b.$$

Bear Locations vs. Release Site

Home range. I calculated the 95% minimum convex polygon (MCP) (Mohr and Stumpf 1966, Jennrich and Turner 1969) using the Animal Movement Analysis Extension to ArcView (Hooge and Eichenlaub 1998) to estimate home ranges of radio-collared bears released on-site. A MCP is constructed by the outer locations obtained for an animal and provides a boundary to the area that the animal was observed (Samuel and Fuller 1996). The 95% MCP is calculated by including 95% of the innermost observations and provides some information on frequency of use within a home range (Ackerman et al. 1990).

Compositional Analysis. Although compositional analysis is usually used to measure habitat use (Aebischer et al. 1993), I applied it to distance zones around each release site to examine the relationship of actual bear locations to release sites. Therefore, I used the area of a distance zone within a bear's home range as a "habitat type" and tested the hypothesis that bear use (i.e., distance from release site) differed from random. Because use of distance zones is the proportion of an animal's trajectory contained within each zone, the sample size is determined by the number of radio tracked animals and not the number of radio locations (Aebischer et al. 1993). Assumptions of compositional analysis are 1) radio locations from each animal provide an unbiased representation of their trajectory, 2) compositions from different animals are equally accurate, and 3) residuals after model fitting exhibit multivariate normality (Aitchison 1986).

For each release site, I created distance zones of 1, 2, 3, 4, 5, and >5 km. The zones, their compositions in each bear's 95% MCP home range, and the proportion of radio locations from each bear within each zone were calculated using ArcView® 3.0 (Figure 2). Because ground telemetry was primarily constrained to the release sites of bears, I excluded most of the ground locations from the analysis to avoid biases associated with the number of radio locations (i.e., if a bear stayed in the vicinity of its release site, I could record daily locations vs. a bear that did not stay near its release site, I could only record weekly locations from the air) and representation of the trajectory that they sampled. Since a zero numerator or denominator in the log-ratio transformation is invalid, a small positive value should be substituted that is smaller than the least recorded nonzero proportion (Aebischer et al. 1993). To preserve a recorded value of 0% in the analysis (i.e., a particular distance zone was available but not used by a bear), I replaced a value of 0% with 0.01%. Using a multivariate analysis of variance test (MANOVA) (SAS Institute, Inc. 1990), I compared used area to available area of the buffers by analyzing the proportional buffer use based on radio locations vs. home range composition (Johnson 3rd order selection) (Johnson 1980). Only bears that were not relocated and had enough locations to create a 95% MCP home range were included in the analysis.

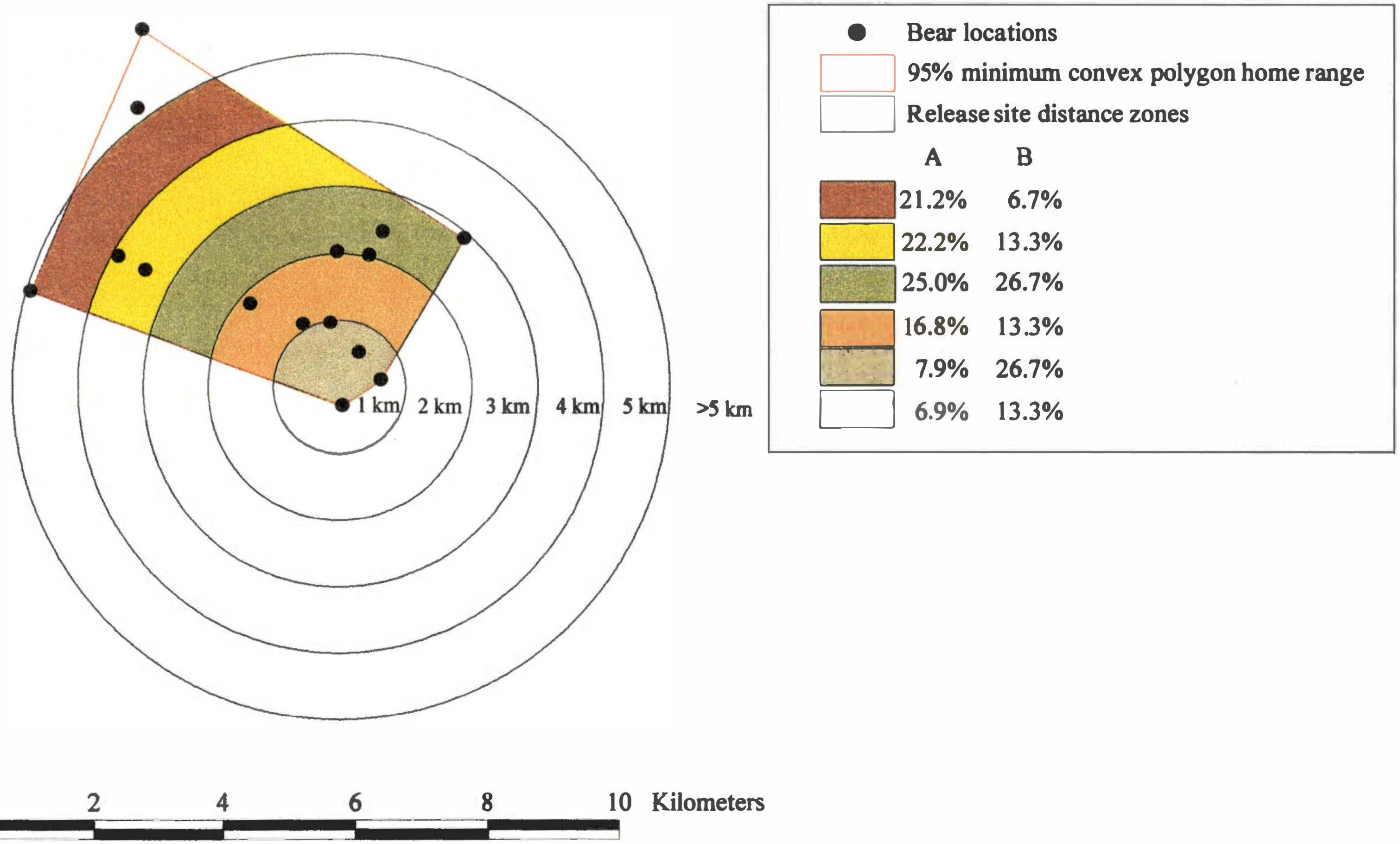


Figure 2. Example of A) proportion of bear home range within each distance zone and B) proportion of bear locations within each distance zone for use with compositional analysis.

CHAPTER IV

RESULTS

Capture and Handling

Between 1997-98, 28 bears (16 males, 12 females) were captured and released on-site a total of 30 times in GSMNP (Table 5). Bears were released at picnic areas (*n* = 14), backcountry campsites (*n* = 10), campgrounds (*n* = 2), parking lots (*n* = 1), and roadsides (*n* = 1). Nine of the 28 bears (32%) released were later relocated as a result of their continued nuisance activity (Table 5). I attached radio-collars to 25 bears (14 males, 11 females) and recorded 570 telemetry locations. Because of the topography and lack of roads in GSMNP, radio locations were primarily limited to aerial telemetry by fixed-winged aircraft.

Capture and On-site Release

From 1990-1998, 63 individual bears (44 males, 13 females, and 6 females with young) accounted for 85 on-site releases (54 males, 20 females, and 11 females with young) in frontcountry areas of GSMNP (Table A.1). The overall success rate for on-site releases in the Park between 1990 and 1998 was 74%.

Model Development. Univariate analyses identified sex, age, time of nuisance activity, capture area, and behavior as significant variables (*P* = 0.1) (Tables 6-11). All of these variables exhibited consistent relationships regarding positive or negative influence on success except for sex (Table 12). Females released on-site had a positive

Table 5. Nuisance black bears captured and on-site released in Great Smoky Mountains National Park, 1997-98.

Bear	Capture Date	Sex	Capture Location	Fate
248	05/20/97	M	Chimneys Picnic Area	Active collar
277	06/05/97	M	Chimneys Picnic Area	Hunter kill
1357	06/12/97	M	Chimneys Picnic Area	Released on-site
280	06/25/97	F	Spence Field Shelter	Illegal kill
285	06/27/97	M	Chimneys Picnic Area	Relocated
1357	06/30/97	M	Chimneys Picnic Area	Hunter kill
175	07/03/97	F	Chimneys Picnic Area	Released on-site
287	07/03/97	F	Cades Cove Picnic Area	Relocated
283	07/04/97	F	Campsite #37	Relocated
288	07/06/97	F	Chimneys Picnic Area	Active collar
291	07/15/97	M	Chimneys Picnic Area	Active collar
175	07/17/97	F	Chimneys Picnic Area	Relocated
1339	07/22/97	M	Cades Cove Picnic Area	Relocated
284	07/28/97	M	Chimneys Picnic Area	Unknown
144	08/05/97	F	Chimneys Picnic Area	Relocated
294	08/07/97	F	Chimneys Picnic Area	Relocated
296	08/11/97	F	Balsam Mountain Campground	Relocated
309	05/10/98	M	Campsite #36	Unknown
308	05/18/98	M	Campsite #38	Active collar
315	05/24/98	M	Campsite #26	Unknown
314	05/24/98	M	Campsite #26	Active collar
316	05/27/98	M	Campsite #17	Active collar
317	06/03/98	F	Russell Field Shelter	Active collar
318	06/10/98	M	Mt. Collins Shelter	Active collar
236	06/18/98	F	Chimneys Picnic Area	Active collar
319	06/24/98	M	Big Creek Campground	Active collar
322	06/26/98	M	Clingmans Dome Parking Lot	Unknown
303	07/18/98	M	Chimneys Picnic Area	Relocated
325	08/05/98	F	Cades Cove Loop Road	Active collar
321	08/12/98	F	Campsite #34	Active collar

Table 6. Univariate logistic regression results to determine correlates of success of nuisance black bears released on-site in Great Smoky Mountains National Park with no observations at the release site within the same year (success definition 1), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
No. of Previous On-site Releases Within Same Year	0.7319	0.6684	1.1991	0.2735	0.154451
No. of Previous On-site Releases Prior to Current Year	-0.1395	0.2851	0.2394	0.6246	-0.059122
Sex (with reference to Male)					
2) Female	0.0884	0.5470	0.0261	0.8716	0.020799
3) Female with cubs	-1.5115	0.7333	4.2483	0.0393	-0.281365
Age	0.0228	0.0885	0.0662	0.7970	0.031661
Season (with reference to Fall/Winter)					
2) Spring	-12.5854	186.5	0.0046	0.9462	-2.430414
3) Summer	-11.9176	186.5	0.0041	0.9491	-2.700366
Time (with reference to Night)					
1) Day	-1.6243	0.5752	7.9732	0.0047	-0.394563
2) Crepuscular	-0.8977	0.5498	2.6654	0.1026	-0.224100
Area (with reference to Other)					
1) Campground	-2.0541	0.9714	4.4714	0.0345	-0.382385
2) Picnic Area	-1.7019	0.8032	4.4892	0.0341	-0.434920
Behavior (with reference to Bold/ Aggressive/Food Conditioned)					
1) Passive/Shy	0.8873	0.4662	3.6862	0.0549	0.236871
Population Estimate	-0.0030	0.0020	2.3393	0.1261	-0.190988
Total Oak	0.0524	0.3686	0.0202	0.8870	0.017408

Table 7. Univariate logistic regression results to determine correlates of success of nuisance black bears released on-site in Great Smoky Mountains National Park with no observations at the release site within the same year (success definition 2), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
No. of Previous On-site Releases Within Same Year	0.5334	0.6639	0.6454	0.4218	0.112549
No. of Previous On-site Releases Prior to Current Year	-0.2403	0.2873	0.6996	0.4029	-0.101866
Sex (with reference to Male)					
2) Female	0.0696	0.5692	0.0150	0.9027	0.016372
3) Female with cubs	-1.7585	0.7377	5.6827	0.0171	-0.327359
Age	-0.0277	0.0900	0.0948	0.7582	-0.038546
Season (with reference to Fall/Winter)					
2) Spring	-11.6153	192.2	0.0037	0.9518	-2.243084
3) Summer	-11.9154	192.2	0.0038	0.9506	-2.699886
Time (with reference to Night)					
1) Day	-1.2470	0.5638	4.8930	0.0270	-0.302915
2) Crepuscular	-0.5539	0.5588	0.9825	0.3216	-0.138278
Area (with reference to Other)					
1) Campground	-1.6895	0.9714	3.0250	0.0820	-0.314505
2) Picnic Area	-1.4945	0.8045	3.4513	0.0632	-0.381920
Behavior (with reference to Bold/ Aggressive/Food Conditioned)					
1) Passive/Shy	0.8005	0.4669	2.9394	0.0864	0.213687
Population Estimate	-0.0026	0.0020	1.6545	0.1983	-0.162808
Total Oak	0.2454	0.3842	0.4078	0.5231	0.081562

Table 8. Univariate logistic regression results to determine correlates of success of nuisance black bears released on-site in Great Smoky Mountains National Park with no observations at the release site within the same year (success definition 3), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
No. of Previous On-site Releases Within Same Year	0.5461	0.7699	0.5031	0.4781	0.115231
No. of Previous On-site Releases Prior to Current Year	-0.2395	0.2969	0.6507	0.4199	-0.101525
Sex (with reference to Male)					
2) Female	0.9445	0.8141	1.3460	0.2460	0.222186
3) Female with cubs	-2.2336	0.7520	8.8225	0.0030	-0.415794
Age	0.00817	0.0991	0.0068	0.9343	0.011368
Season (with reference to Fall/Winter)					
2) Spring	-11.4408	215.7	0.0028	0.9577	-2.209384
3) Summer	-11.6127	215.7	0.0029	0.9571	-2.631285
Time (with reference to Night)					
1) Day	-2.3514	0.6796	11.9699	0.0005	-0.571170
2) Crepuscular	-1.0704	0.7077	2.2881	0.1304	-0.267236
Area (with reference to Other)					
1) Campground	-1.3122	0.9848	1.7755	0.1827	-0.244270
2) Picnic Area	-0.8832	0.8140	1.1771	0.2779	-0.225699
Behavior (with reference to Bold/ Aggressive/Food Conditioned)					
1) Passive/Shy	1.5550	0.5263	8.7301	0.0031	0.415128
Population Estimate	-0.0030	0.00221	1.8912	0.1691	-0.191521
Total Oak	-0.0465	0.4112	0.0128	0.9100	-0.015452

Table 9. Univariate logistic regression results to determine correlates of success of nuisance black bears released on-site in Great Smoky Mountains National Park with no observations at the release site in successive years (success definition 4), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
No. of Previous On-site Releases Within Same Year	-1.2477	0.7518	2.7542	0.0970	-0.287688
No. of Previous On-site Releases Prior to Current Year	-2.5212	1.1618	4.7095	0.0300	-0.701776
Sex (with reference to Male)					
2) Female	-2.7695	0.7585	13.3299	0.0003	-0.715533
3) Female with cubs	-1.9810	1.5115	1.7178	0.1900	-0.214111
Age	-0.2664	0.1499	3.1604	0.0754	-0.329581
Season (with reference to Fall/Winter)					
2) Spring	0.5596	1.5469	0.1309	0.7175	0.113321
3) Summer	-0.8473	1.1675	0.5267	0.4680	-0.205608
Time (with reference to Night)					
1) Day	0.0488	0.9271	0.0028	0.9580	0.009880
2) Crepuscular	-0.7985	0.6684	1.4270	0.2323	-0.206307
Area (with reference to Other)					
1) Campground	-12.4013	155.9	0.0063	0.9366	-2.224786
2) Picnic Area	-11.8752	155.9	0.0058	0.9393	-3.068133
Behavior (with reference to Bold/ Aggressive/Food Conditioned)					
1) Passive/Shy	0.4279	0.6730	0.4043	0.5249	0.103845
Population Estimate	-0.0008	0.00292	0.0671	0.7956	-0.043422
Total Oak	0.2242	0.5110	0.1926	0.6608	0.076164

Table 10. Univariate logistic regression results to determine correlates of success of nuisance black bears released on-site in Great Smoky Mountains National Park with no management action necessary at the release site in successive years (success definition 5), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
No. of Previous On-site Releases Within Same Year	-1.3486	0.7603	3.1461	0.0761	-0.310953
No. of Previous On-site Releases Prior to Current Year	-2.6441	1.1671	5.1324	0.0235	-0.735994
Sex (with reference to Male)					
2) Female	-2.4918	0.7424	11.2659	0.0008	-0.643802
3) Female with cubs	-1.9810	1.5115	1.7178	0.1900	-0.214111
Age	-0.2130	0.1476	2.0831	0.1489	-0.263467
Season (with reference to Fall/Winter)					
2) Spring	0.5596	1.5469	0.1309	0.7175	0.113321
3) Summer	-0.7324	1.1692	0.3924	0.5310	-0.177719
Time (with reference to Night)					
1) Day	0.0488	0.9271	0.0028	0.9580	0.009880
2) Crepuscular	-0.5390	0.6779	0.6322	0.4265	-0.139258
Area (with reference to Other)					
1) Campground	-12.4456	159.4	0.0061	0.9378	-2.232740
2) Picnic Area	-11.7950	159.4	0.0055	0.9410	-3.047424
Behavior (with reference to Bold/ Aggressive/Food Conditioned)					
1) Passive/Shy	0.5596	0.6788	0.6797	0.4097	0.135798
Population Estimate	0.0010	0.00300	.01093	0.7409	0.057036
Total Oak	0.4570	0.5478	0.6960	0.4041	0.155233

Table 11. Univariate logistic regression results to determine correlates of success of nuisance black bears released on-site in Great Smoky Mountains National Park with no relocation from the release site in successive years (success definition 6), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
No. of Previous On-site Releases Within Same Year	-0.5375	0.7916	0.4610	0.4972	-0.123921
No. of Previous On-site Releases Prior to Current Year	-0.7297	0.6096	1.4327	0.2313	-0.203103
Sex (with reference to Male)					
2) Female	-2.9549	1.1393	6.7273	0.0095	-0.763447
3) Female with cubs	-3.4657	1.7410	3.9625	0.0465	-0.374584
Age	-0.1133	0.1763	0.4132	0.5203	-0.140219
Season (with reference to Fall/Winter)					
2) Spring	11.5693	230.0000	0.0025	0.9599	2.342759
3) Summer	0.1018	1.1938	0.0073	0.9321	0.024699
Time (with reference to Night)					
1) Day	-0.6506	0.9799	0.4408	0.5067	-0.131742
2) Crepuscular	0.1967	0.1967	0.0447	0.8325	0.050823
Area (with reference to Other)					
1) Campground	-12.9556	205.7000	0.0040	0.9498	-2.324237
2) Picnic Area	-11.1638	205.7000	0.0029	0.9567	-2.884355
Behavior (with reference to Bold/ Aggressive/Food Conditioned)					
1) Passive/Shy	1.3291	0.8003	2.7581	0.0968	0.322533
Population Estimate	0.0034	0.0040	0.7526	0.3857	0.198025
Total Oak	0.9478	0.8209	1.3331	0.2483	0.321958

Table 12. Summary of univariate logistic regression models to determine success of on-site releases for nuisance black bears in Great Smoky Mountains National Park, 1990-98.

Variable	Frequency of Significance ($P < 0.10$)	Negative	Positive
	Frequency and Influence of Parameter Estimate		
No. of previous releases on-site within the same year	2	2	0
No. of previous releases on-site in years prior	2	2	0
Sex	6		
1) Male		2	4
2) Female		3	3
3) Female with young		6	0
Age	1	1	0
Release season	0		
1) Fall/Winter		-	-
2) Spring		-	-
3) Summer		-	-
Time of nuisance activity	3		
1) Day		3	0
2) Crepuscular		3	0
3) Night		0	3
Capture area	2		
1) Campground		2	0
2) Picnic area		2	0
3) Other		0	2
Behavior	4		
1) Passive/shy		0	4
2) Beggar/food conditioned/bold/aggressive		4	0
Population estimate	0	-	-
Total oak	0	-	-

relationship for success within the same year of on-site releases (success definitions 1, 2,and 3), but a negative relationship for success in successive years (success definitions 4, 5, and 6) (Table 12). Males also exhibited inconsistent relationships regarding positive (success definitions 2, 4, 5, and 6) or negative (success definitions 1 and 3) influence on the success of on-site releases (Table 12).

The number of previous releases on-site within the same year of capture and in years prior to current capture were significant for success definitions 4 and 5 (Tables 9 and 10). To avoid biases related to the independence of multiple captures for the same bear, I performed the multivariable analyses for success definition 4 and 5 using only the initial capture of each individual. In all the other models, I treated each release as a separate observation regardless of whether the previous release was within the same year or in a year prior to current capture.

Univariate analysis for the model selection procedure indicated that 6 variables should be considered for success definition 1 (Table 6), 7 variables for success definition 2 (Table 7), 7 variables for success definition 3 (Table 8), 4 variables for success definition 4 (Table 9), 5 variables for success definition 5 (Table 10), and 6 variables for success definition 6 (Table 11).

Multiple variable models were developed based on the results of the univariate analysis. The model for no observations at the release site within the same year (model 1) was best explained by 3 variables (Table 13). This model fit the data (Hosmer-Lemeshow goodness-of-fit statistic = 6.5007, 7 df, $P = 0.4826$) and explained 30.4% of the variation (Table 13). The model for no management actions necessary at the release site within the same year (model 2) fit the data (Hosmer-Lemeshow goodness-of-fit

Table 13. Multiple variable logistic regression results to determine correlates of success for nuisance black bears captured and on-site released in Great Smoky Mountains National Park with no observations at the release site within the same year (model 1), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
Intercept	4.9379	1.3767	12.8646	0.0003	.
Time (with reference to Crepuscular/Night)					
1) Day	-2.3408	0.7193	10.5885	0.0011	-0.568591
Area (with reference to Other)					
1) Campground	-2.4692	1.1136	4.9166	0.0266	-0.459654
2) Picnic Area	-2.3401	0.9579	5.9680	0.0146	-0.598016
Population Estimate	-0.00564	0.00248	5.1575	0.0231	-0.355445

Hosmer-Lemeshow goodness-of-fit statistic = 6.5007, 7 df, P=0.4826
Maximum rescaled R^2 = 0.3041

statistic = 1.1452, 3 df, P = 0.7662) and explained 20.0% of the variation (Table 14). The model for no relocation within the same year of release (model 3) fit the data (Hosmer-Lemeshow goodness-of-fit statistic = 5.8735, 7 df, P = 0.5546) and explained 50.2% of the variation (Table 15). The models for no observations (model 4) and no management action necessary at the release site in successive years (models 5) were best explained by 1 variable representing 35.0 % and 27.0% of the variation, respectively (Table 16 and 17); however, Hosmer-Lemeshow goodness-of-fit statistic for these 2 models could not be calculated. The model for no relocation from release site in successive years (model 6) was best explained by a 1 variable model that explained 34.5% of the variation (Table 18). The goodness-of-fit statistic could not be calculated for this model because of the unbalanced proportion of successes to failures in the sample.

Model Validation. I selected probability cut-off points ranging from 0.38 for model 3 to 0.68 for model 6 to classify an observation as a success or failure (Table 19). The overall correct prediction rate from the jackknife procedures ranged from 71.8% to 85.9% for the 6 multivariable models (Table 19). Reliability of the 6 models ranged from 0.68 for model 6 to 0.83 for model 3.

Model Application. I used the models 1, 2, and 3 to predict success of on-site releases using all possible combinations of variable values (Table B.1). I used the highest (x = 510, 1997) and the mean ($\bar{x}$=313) population estimates from the data to create scenarios for models 1 and 3. Relative probabilities of success ranged from 0.06 - 0.96 ($\bar{x}$ = 0.47) for model 1, 0.11-0.88 ($\bar{x}$ = 0.32) for model 2, and 0.00-0.96 ($\bar{x}$ = 0.30) for model 3 (Table B.1).

Table 14. Multiple variable logistic regression results to determine correlates of success for nuisance black bears captured and on-site released in Great Smoky Mountains National Park with no management action necessary at the release site within the same year (model 2), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
Intercept	1.9454	0.6110	10.1388	0.0015	.
Time (with reference to Crepuscular/Night)					
1) Day	-1.2198	0.5856	4.3396	0.0372	-0.296310
Area (with reference to Campground/ Other)	-1.1346	0.6142	3.4121	0.0647	-0.289942
1) Picnic Area	1.1346	0.6142	3.4121	0.0647	0.289942
2) Campground/ Other					
Sex (with reference to Male/Female)					
3) Female with young	-1.7271	0.7543	5.2427	0.0220	-0.321514

Hosmer-Lemeshow goodness-of-fit statistic = 1.1452, 3 df, P=0.7662
Maximum rescaled R^2 = 0.2008

Table 15. Multiple variable logistic regression results to determine correlates of success of nuisance black bears captured and on-site released in Great Smoky Mountains National Park with no relocation necessary from the release site within the same year (model 3), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
Intercept	7.1463	1.9403	13.5657	0.0002	.
Sex (with reference to Male/Female with young)					
2) Female	3.0027	1.0127	8.7913	0.0030	0.706385
Time (with reference to Night)					
1) Day	-4.7471	1.1893	15.9322	0.0001	-1.153101
2) Crepuscular	-1.7674	0.8829	4.0075	0.0453	-0.441242
Population Estimate	-0.0128	0.00411	9.6737	0.0019	-0.804606

Hosmer-Lemeshow goodness-of-fit statistic = 5.8735, 7 df, P=0.5546
Maximum rescaled R^2 = 0.5015

Table 16. Multiple variable logistic regression results to determine correlates of success for nuisance black bears captured and on-site released in Great Smoky Mountains National Park with no observations at the release site in successive years (model 4), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
Intercept	2.5257	0.7348	8.0885	0.0045	-0.686204
Sex (with reference to Male/Female with young)					
2) Female	-2.7081	0.9522	8.0885	0.0045	-0.686204

Hosmer-Lemeshow goodness-of-fit statistic could not be calculated.
Maximum rescaled $R^2 = 0.3504$

Table 17. Multiple variable logistic regression results to determine correlates of success for nuisance black bears captured and on-site released in Great Smoky Mountains National Park with no management action necessary at the release site in successive years (model 5), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
Intercept	2.5257	0.7348	11.8135	0.0006	.
Sex (with reference to Male/Female with young)					
2) Female	-2.3434	0.9522	6.0569	0.0139	-0.593805

Hosmer-Lemeshow goodness-of-fit statistic could not be calculated.
Maximum rescaled $R^2 = 0.2695$

Table 18. Multiple variable logistic regression results to determine correlates of success of nuisance black bears captured and on-site released in Great Smoky Mountains National Park with no relocation necessary from the release site in successive years (model 6), 1990-98.

Variable	Parameter Estimate	Standard Error	Wald X^2	Prob.	Standardized Estimate
Intercept	3.4657	1.0155	11.6473	0.0006	.
Sex (with reference to Male)					
2) Female	-2.9549	1.1393	6.7273	0.0095	-0.763447
3) Female with young	-3.4657	1.7410	3.9625	0.0465	-0.374584

Hosmer-Lemeshow goodness-of-fit statistic = 0, 1 df, P=1.0000
Maximum rescaled R^2 = 0.3452

Table 19. Summary of classification tables of logistic regression models to determine success of capture and on-site release for nuisance black bears in Great Smoky Mountains National Park, 1990-98.

Model #	Prob. Cut-off Level	% Correct	% Sensitivity[a]	% Specificity[b]	% False Pos.[c]	% False Neg.[d]	Reliability[e]
1	0.50	75.3	84.0	62.9	23.6	26.7	0.74
2	0.50	71.8	88.9	41.9	27.3	31.6	0.69
3	0.38	85.9	95.2	59.1	13.0	18.8	0.83
4	0.52	81.6	83.3	75.0	7.4	45.5	0.75
5	0.60	78.9	80.6	71.4	7.4	54.5	0.71
6	0.68	74.5	74.4	75.0	5.9	64.7	0.68

[a]Correct prediction of on-site release success (a)
[b]Correct prediction of on-site release failure (b)
[c]On-site release success predicted for actual failure (c)
[d]On-site release failure predicted for actual success (d)
[e](a + b) / (a + b + c + d) Marcot et al. (1983)

Survival

I monitored 23 bears (12 males, 11 females) between May 1997 to December 1998 for survival analysis. Of the 12 radio-collared males, 3 were relocated and their collars removed, 2 were harvested, and 7 were active and censored at the end of the study (Table 20). Of the 11 radio-collared females, 6 were relocated and their collars removed, and 5 were active and censored at the end of the study (Table 20).

Survival for the study period was 0.71 (95% CI = 0.50-0.93) (Figure 3). Annual survival of bears released on-site in 1997 and 1998 was 0.71 (95% CI = 0.28-1.0) and 1.0 (95% CI = 0.74-1.0) (Figure 4), respectively. Survival functions (χ_1^2 = 2.571, P = 0.11) and overall survival rates (Z = 1.30, P = 0.09) for 1997 and 1998 did not differ. Survival for male and female bears during the entire study period was 0.50 (95% CI = 0.24-0.76) and 1.00 (95% CI = 0.76-1.00) (Figure 5), respectively. Although survival functions between the sexes did not differ (χ_1^2 = 1.500, P = 0.22), overall survival rates between the sexes were different (Z = 3.74, P <0.001).

Bear Locations vs. Release Site

Home Range. I calculated 95% MCP home ranges for 14 bears (9 males, 5 females) released on-site. Home ranges ranged from 3.9 - 272.9 km^2 ($\bar{x}$ = 92.0 km^2) for males and 3.3 - 20.2 km^2 ($\bar{x}$ = 8.4 km^2) for females (Table 21; Figure 6).

Compositional Analysis. I used telemetry data from 14 bears in the analysis. The distance zone >5 km from release sites had the highest number of radio locations (Table 22) and greatest proportional composition for home range area and number of locations

Table 20. Fate of radio-collared black bears released on-site in Great Smoky Mountains National Park, 1997-98.

Bear ID	Capture Date	Sex	Capture Location	Fate	Censor/ Mortality Date
248	05/20/97	M	Chimneys Picnic Area	Active	12/98
277	06/05/97	M	Chimneys Picnic Area	Hunter kill	10/97
1357	06/12/97	M	Chimneys Picnic Area	Hunter kill	10/97
285	06/27/97	M	Chimneys Picnic Area	Relocated	07/97
175	07/03/97	F	Chimneys Picnic Area	Relocated	10/97
287	07/03/97	F	Cades Cove Picnic Area	Relocated	07/97
283	07/04/97	F	Campsite #37	Relocated	08/97
288	07/06/97	F	Chimneys Picnic Area	Active	12/98
291	07/15/97	M	Chimneys Picnic Area	Active	12/98
1339	07/22/97	M	Cades Cove Picnic Area	Relocated	08/97
144	08/05/97	F	Chimneys Picnic Area	Relocated	10/97
294	08/07/97	F	Chimneys Picnic Area	Relocated	08/97
296	08/11/97	F	Balsam Mountain Campground	Relocated	08/97
308	05/18/98	M	Campsite #38	Active	12/98
314	05/24/98	M	Campsite #26	Active	12/98
316	05/27/98	M	Campsite #17	Active	12/98
317	06/03/98	F	Russell Field Shelter	Active	12/98
318	06/10/98	M	Mt. Collins Shelter	Active	12/98
236	06/18/98	F	Chimneys Picnic Area	Active	12/98
319	06/24/98	M	Big Creek Campground	Active	12/98
303	07/18/98	M	Chimneys Picnic Area	Relocated	07/98
325	08/05/98	F	Cades Cove Loop Road	Active	12/98
321	08/12/98	F	Campsite #34	Active	12/98

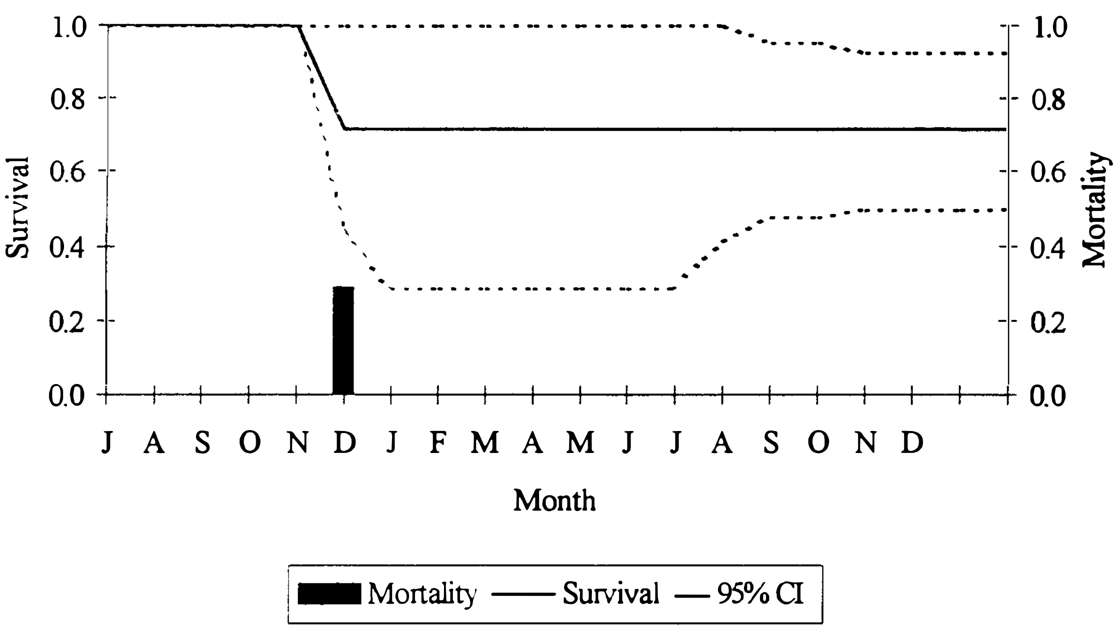
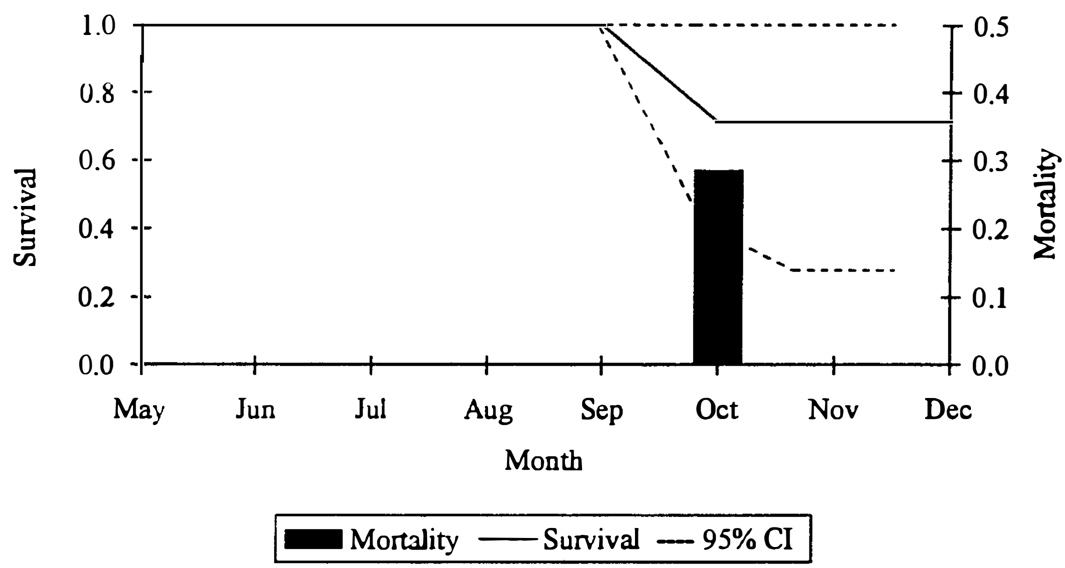


Figure 3. Survival (95% CI) and mortality rates for nuisance black bears released on-site in Great Smoky Mountains National Park, May 1997 - December 1998.

(a)



(b)

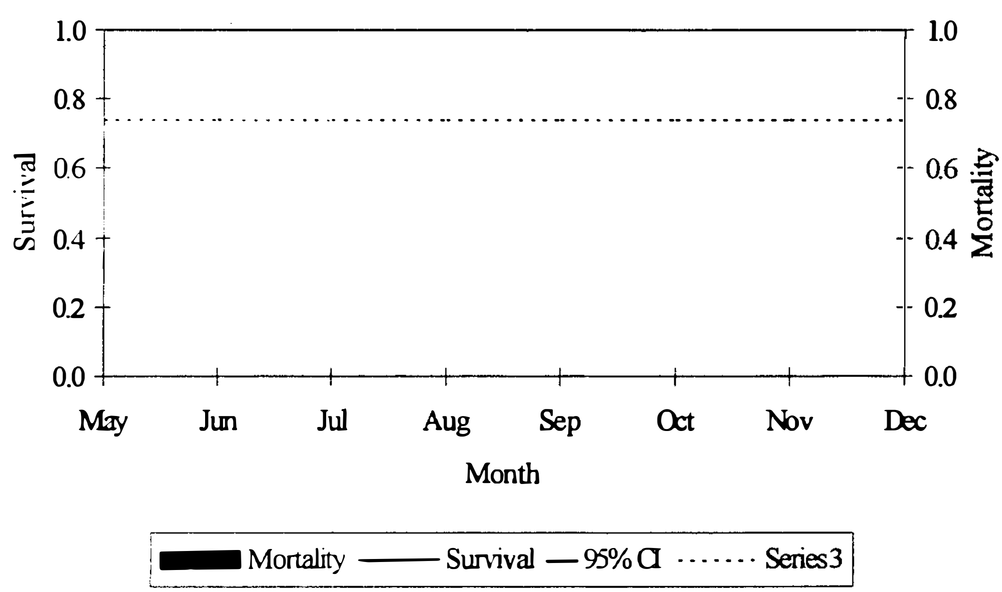


Figure 4. Survival (95% CI) and mortality rates for nuisance black bears released on-site in Great Smoky Mountains National Park for (a) 1997 and (b) 1998.

(a)

(b)

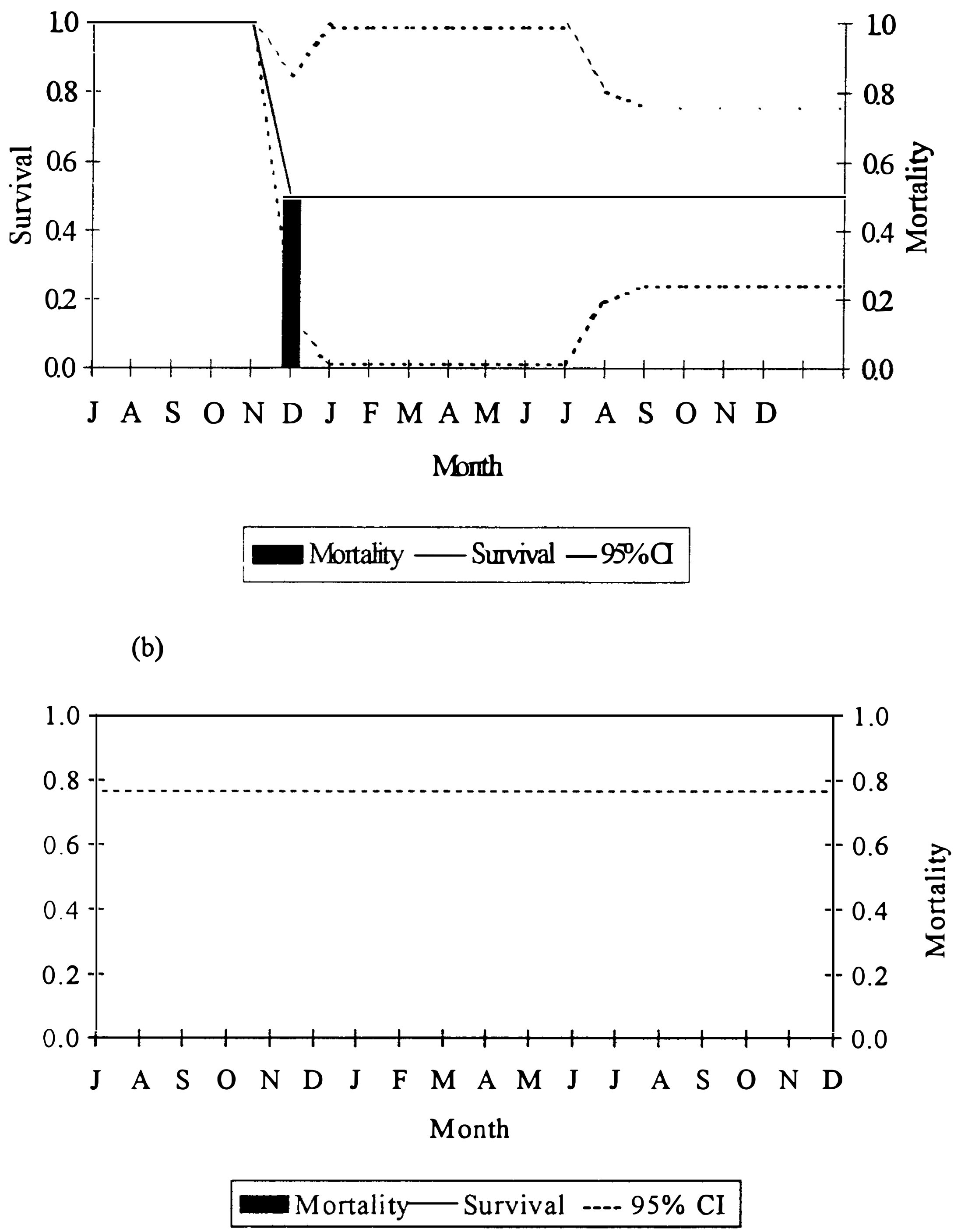


Figure 5. Survival (95% CI) and mortality rates for nuisance black bears released on-site in Great Smoky Mountains National Park for (a) males and (b) females, May 1997 - December 1998.

Table 21. Minimum convex polygon home ranges (95%) for nuisance black bears captured and on-site released in Great Smoky Mountains National Park, 1997-98.

Bear ID	**Sex**	**No. Locations**	**Home Range Area (km^2)**
236	F	9	6.0
248	M	17	61.3
277	M	13	203.9
288	F	15	20.2
291	M	16	55.9
308	M	15	42.0
314	M	17	3.9
316	M	16	92.3
317	F	12	7.8
318	M	16	49.6
319	M	14	46.0
321	F	8	3.3
325	F	7	4.9
1357	M	13	272.9
Mean		13.4	62.1

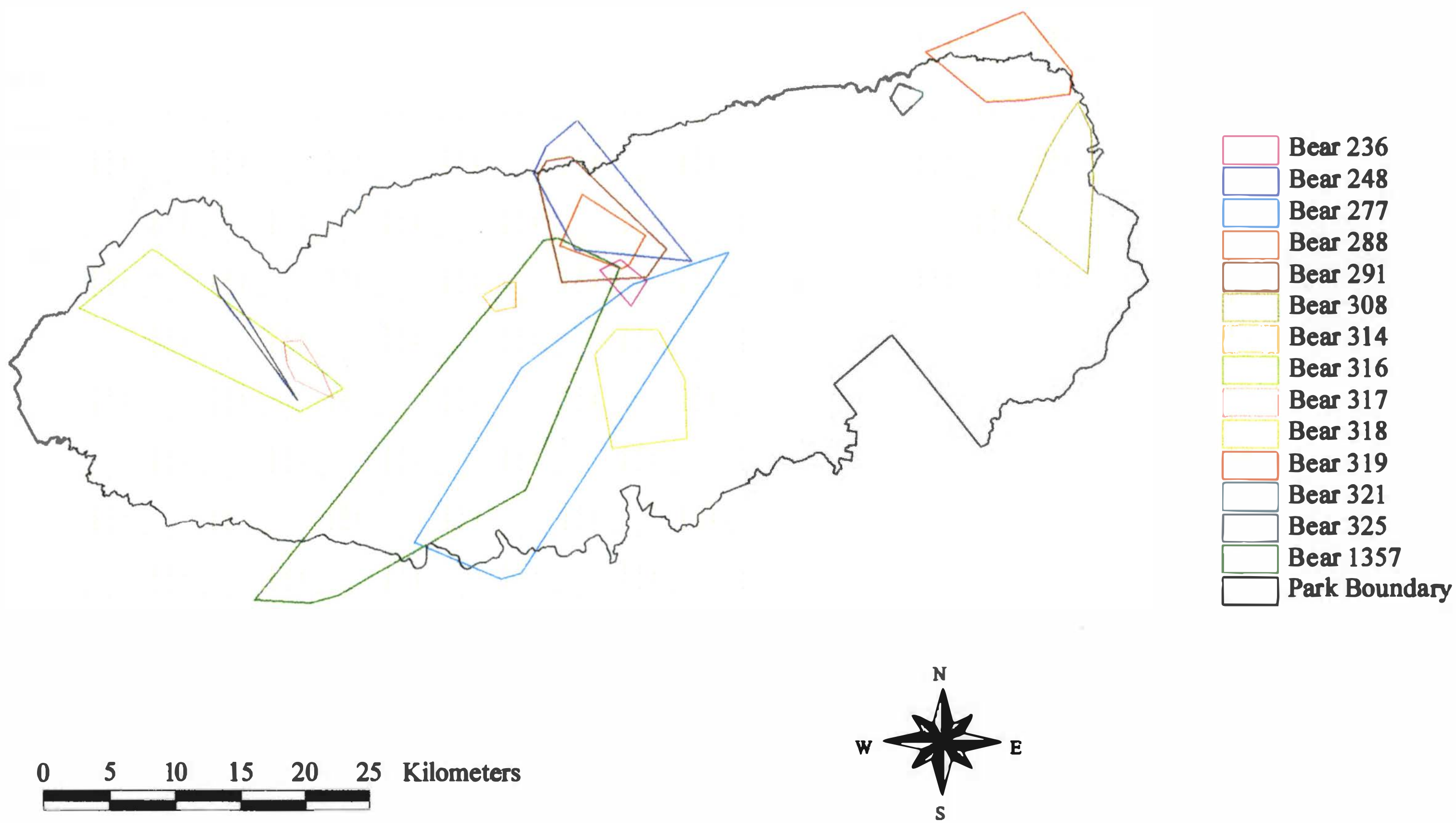


Figure 6. Home ranges (95% minimum convex polygon) of nuisance black bears captured and on-site released in Great Smoky Mountains National Park, 1997-98.

Table 22. Locations within each distance zone for nuisance black bears released on-site in Great Smoky Mountains National Park, 1997-98.

Distance Zone (km)	Locations	% Total
1	39	20.7
2	33	17.6
3	22	11.7
4	18	9.6
5	9	4.8
>5	67	35.6
Total	188	100.0

within each zone (Table 23). However, bear use between the buffer zones surrounding the release sites did not differ (5 df, $P = 0.31$). Because there was no difference in use of the buffer zones, rank scores were ignored.

Table 23. Proportions of home range area and number of locations within each distance zone of nuisance black bears released on-site in Great Smoky Mountains National Park, 1997-98.

	Proportion of Home Range Area within each Distance Zone						Proportions of Locations within each Distance Zone					
Bear	**1 km**	**2 km**	**3 km**	**4 km**	**5 km**	**>5 km**	**1 km**	**2 km**	**3 km**	**4 km**	**5 km**	**>5 km**
319	---	2.4	6.7	9.3	11.3	70.3	---	14.3	21.4	21.4	0.0	42.9
291	5.6	12.7	16.6	16.2	14.3	34.7	6.3	6.3	6.3	12.5	6.3	62.5
288	7.9	16.8	25.0	22.2	21.2	6.9	26.7	13.3	26.7	13.3	6.7	13.3
248	0.3	4.9	10.1	15.2	15.5	54.0	0.0	0.0	0.0	5.9	0.0	94.1
277	---	0.1	1.6	3.1	4.5	90.6	---	7.7	0.0	0.0	0.0	92.3
236	28.7	47.5	23.3	0.5	---	---	33.3	33.3	22.2	11.1	---	---
1357	0.2	0.8	1.4	1.9	2.5	93.2	15.4	0.0	0.0	0.0	23.1	61.5
317	20.1	50.4	20.9	8.3	0.4	---	33.3	41.7	16.7	0.0	8.3	---
308	6.4	14.2	21.4	26.6	16.8	14.6	0.0	6.7	13.3	33.3	20.0	26.7
314	69.7	30.3	---	---	---	---	52.9	47.1	---	---	---	---
325	30.6	21.5	12.2	10.3	8.6	16.8	71.4	0.0	14.3	0.0	0.0	14.3
321	58.3	41.7	---	---	---	---	62.5	37.5	---	---	---	---
316	3.4	7.6	10.7	9.4	7.1	61.8	31.3	12.5	12.5	18.8	0.0	25.0
318	2.6	8.5	11.2	13.5	13.9	50.4	6.3	31.3	31.3	6.3	0.0	25.0
Mean	16.7	18.5	11.5	9.8	8.3	35.2	24.2	18.0	11.8	8.8	4.6	32.7

CHAPTER V

DISCUSSION

Capture and On-site Release

The primary objective of the models was to identify the key variables that affect the success of capture and on-site releases for nuisance black bears in GSMNP. The univariate results indicated that several variables were associated with the various success definitions (Table 12). Sex, behavior, and time of nuisance activity were the most influential variables. Other influential variables included capture area and age. Consistent negative relationships with success were identified for females with young, day or crepuscular active bears, bears exhibiting bold or food conditioned behavior, bears captured in campgrounds or picnic areas, and older bears. Consistent positive relationships with success were identified for bears exhibiting passive or shy behavior, night active bears, and bears released on-site in areas other than campgrounds and picnic areas.

Sex was the only variable to exhibit inconsistent relationships among the success definitions. Females released on-site were more successful than males for the definitions related to success within the same year as capture (success definitions 1, 2, and 3). However, females were less successful than males for the definitions related to success in subsequent years (success definitions 4, 5, and 6). These results could stem from differences in home range size between males and females (Gillin et al. 1994). Males in GSMNP tend to have larger home ranges than females (Garshelis and Pelton 1981, Quigley 1982, Carr 1983, van Manen 1994). Thus, male home ranges are more likely to include areas outside GSMNP. Bears occupying areas outside GSMNP are at greater risk to additional mortality factors, such as hunting, poaching, depredation kills, and vehicular collisions. Therefore, males may be more susceptible to these mortality factors (Pelton 1982) and may not be available for capture in successive years. Of the 6 radio-collared males with home ranges that included areas outside GSMNP, 2 died outside GSMNP as a result of hunting. Additionally, home range size may play a role in females being more likely to cause problems in successive years (Gillin et al. 1994). The smaller home range for females may affect the proximity of their movements in relation to the release site, thus increasing the likelihood to eventually return to the developed area.

Bears entering developed areas during the day, as opposed to night or dusk (crepuscular activity), resulted in a lower probability of success when captured and released on-site. Bears are naturally wary of humans and tend to avoid humans and developed areas (Herrero 1985, Mattson 1990). However, bears are also curious animals (Bacon and Burghardt 1976) and may also be attracted to these areas by the smell of human food and garbage (Herrero 1985, Rogers 1989). Initially, bears enter these areas at night when human activity is absent or decreased (Servheen 1981, Herrero 1985, Nadeau 1989). If unnatural food sources are readily available to bears in these areas, bears may become habituated and food conditioned to humans (McCullough 1982, Herrero 1985, Gilbert 1989). Therefore, time of nuisance bear activity may indicate the level of habituation and food conditioning. The results of the univariate analyses supported the argument that time of nuisance bear activity was an indicator of the level of habituation and food conditioning, because the probability of success was greater for releases of bears that were active at night compared to dusk, and dusk compared to day.

Furthermore, bears that were bold and aggressive were less successful than bears that were shy and passive. A bear that is active during the day is more likely to be bolder and less fearful of humans than a bear that is active at night.

The univariate results also indicated that bears released on-site in campgrounds or picnic areas were less successful than bears released in other areas, such as parking lots or roadsides. Bears released on-site at parking lots or roadsides may be less likely to return because these areas do not provide constant sources of human foods or attractants that are prevalent in campgrounds and picnic areas.

Although the univariate results identified important variables, the multiple variable models helped define the combination of variables that most influenced success of on-site releases. These models evaluated short-term (success within the same year as release) and long-term (success in subsequent years after release) success of on-site releases. All the short-term models (models 1, 2, and 3) identified time of nuisance activity as an important factor affecting success. All 3 models exhibited negative relationships with day active bears. Furthermore, bears that were crepuscular active had a higher likelihood of being relocated (model 3) than bears that were active at night. The results of the short-term models were consistent with the univariate analysis in identifying time of nuisance activity as an important factor associated with success, and further supported the argument that time of nuisance activity possibly reflects the level of habituation and food conditioning.

The short-term models for no observations at the release site (model 1) and no management action necessary at the release site (model 2) identified capture area as an important variable affecting success. Success was negatively associated with bears captured in campgrounds and picnic areas for model 1; however, model 2 indicated a negative relationship for picnic areas only. The negative relationship of picnic areas compared to campgrounds and other developed areas for model 2 may be a result of the time of day and amount of use by humans. Picnic areas may be less of a risk to bears than campgrounds or other developed areas because of the absence of humans at night and the abundance of human related foods available from human use during the day. In contrast, entering a campground may be a higher risk to a bear because of the constant presence of humans at all hours. Thus, bears that are released in picnic areas, as opposed to campgrounds, may be more difficult to deter from the site because of the decreased risks involved with entering the area after release.

The short-term models for no management action necessary at the release site (model 2) and no relocation from the release site (model 3) indicated a negative relationship with success for females with cubs. Model 3 also exhibited a negative relationship with success for males. Females with cubs have greater nutritional demands than females without cubs or males (Mattson 1990, Riley et al. 1994), thus explaining why they may be less successful in being deterred from human use areas that may provide high energy gains in the form of human foods (Rogers 1976). Additionally, females with young may be forced to use suboptimal habitat (i.e., areas closer to human developments) to protect their cubs from adult males, especially during the breeding season (LeCount 1986, Mattson et al. 1986, Mattson 1990). This habitat partitioning could affect the amount of risk a female with young is willing to take in order to meet her nutritional requirements.

The results of the short-term models agreed with the univariate analysis except for the population estimate variable. Although not identified as a significant variable in the univariate analysis, the population estimate was identified as an important variable for models 1 and 3. Both models suggested that increased population density has a negative effect on success of on-site releases. Frequency of contact between bears and humans in a given area is likely to increase as bear density increases (Keating 1986, Mattson 1990). With increased density, competition for food resources may make it more difficult to discourage bears that are habituated from using developed areas to obtain food resources.

The models that evaluated long-term success of on-site releases (models 4, 5, and 6) all exhibited negative relationships with success for females (Tables 16, 17, and 18). As mentioned above in the discussion of the univariate models, this negative relationship may be explained by the difference in home range size between males and females. Additionally, females with young exhibited a negative relationship with success for no relocation from the release site in successive years (model 6) (Table 18). Two females with cubs (#144 and #175) were captured in Chimneys Picnic Area (CPA) in 1997, and both of these bears had been captured in CPA with cubs in previous years. Another female (#236) was recaptured in CPA in 1998 without cubs, but had been captured in previous years when she did have cubs. Females may use CPA in search of food during years of nutritional stress, particularly when they have young. The hard mast failure in 1997 and possible shortages of soft mast in the area surrounding CPA could have caused some nutritional stress.

Although the fit of the long-term models could not be calculated, the models consistently identified sex and family group size as the key factors affecting success.

Reliability values for the 3 models were comparable to the short-term models (Table 18). Although the long-term models may have limited capabilities to managers for direct application when compared to the short-term models, they were beneficial in identifying sex and family group size as the possible factors affecting long-term success of capture and release on-site.

Important factors related to the success of capture and on-site release were identified by the multiple variable models. However, the models only accounted for <50% of the variation associated with success. Non-biological factors, such as visitor compliance with food storage regulations, and other biological factors that were not measured likely contributed to the success of on-site releases.

Several studies have demonstrated the effect of annual food production on the frequency of nuisance bear activity (Schorger 1946, Rogers 1976, Garshelis 1989, Mattson et al. 1992, Noyce and Garshelis 1997). In the southern Appalachians, black bears primarily eat berries in late spring through late summer and acorns in the fall (Beeman and Pelton 1976, Eagle and Pelton 1983, Pelton 1989). Data from annual hard mast surveys from GSMNP were used in the models, but were not a significant variable affecting the success of on-site releases. However, abundance of soft mast was not included in the models because of missing data for years prior to 1994. Seasonal distribution of nuisance bear captures in the current study was concentrated in the summer (Figure 7) when soft mast was the primary food source. As with hard mast in the Southern Appalachians, soft mast production is highly variable (Powell and Seaman 1990). The variability in the production of soft mast may affect bear movements resulting in annual fluctuations in the frequency of nuisance bears (Garshelis 1989).

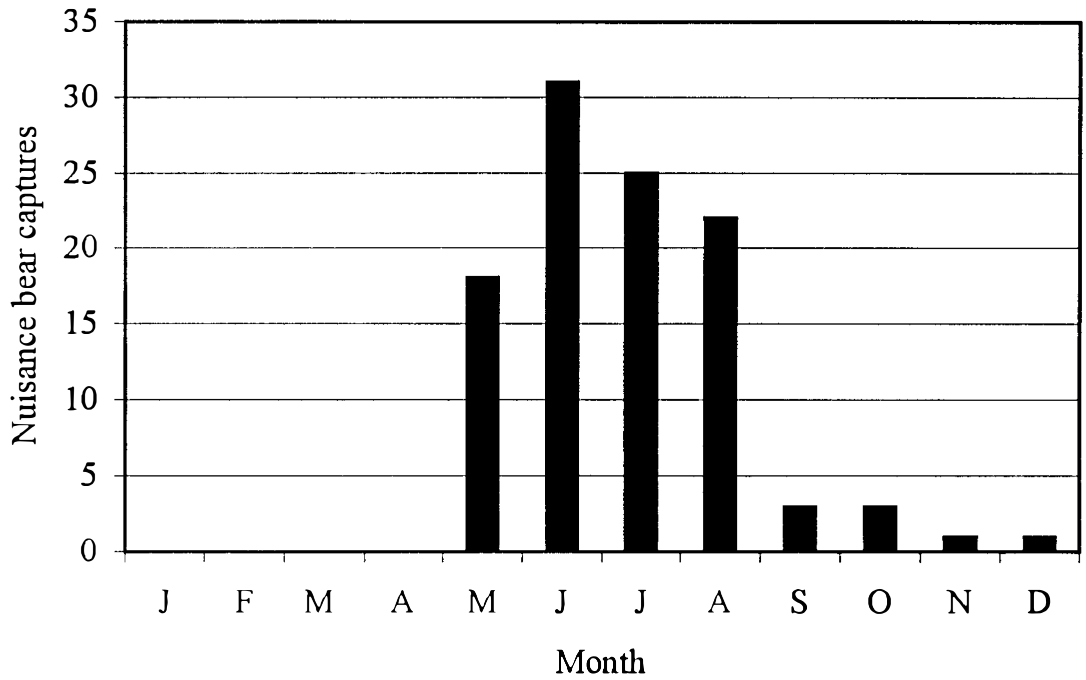


Figure 7. Seasonal distribution of on-site releases (n = 105) of nuisance bears in Great Smoky Mountains National Park, 1990-98.

Thus, soft mast could have an effect, not only on the number of nuisance bears, but also on the success of on-site releases.

Models are any representation of some part of the real world (Morrison et al. 1992). Researchers and managers should test models during the building and application process (Marcot et al. 1983). Model validity refers to the performance standards and criteria of a model and provides a measure of model credibility, realism, generality, precision, breadth, and depth (Marcot et al. 1983). The models in my study were validated by calculating reliability (Marcot et al. 1983) and the Hosmer-Lemeshow goodness-of-fit statistic (Hosmer and Lemeshow 1989). The best validation method to test models is to use independent data (Capen et al. 1986), but exclusion of observations from analysis for validation would have decreased sample sizes. However, future records of on-site releases in GSMNP can be used to test the accuracy and precision.

Survival

The only previous survival estimate for nuisance bears released on-site was between 0.40 and 0.59 for males in Arkansas (Shull 1994). These estimates were similar to survival of males in this study ($\hat{S}$=0.50).

Human-induced mortality, especially hunting, is the major source of mortality for adult black bears (Rogers 1976). I recorded 2 mortalities of bears released on-site during the study. Both mortalities were males (#277 and #1357) and occurred outside the boundary of GSMNP as a result of legal hunting in October 1997 (Table 21). Both harvested bears had home ranges that contained area outside the boundary of GSMNP (Figure 6). No bears were censored during the study because of lost contact or unknown fate, therefore any additional mortality of bears released on-site would have been detected.

Relocated bears may have lower survival rates related to the stress of translocation and lack of familiarity with the release area. A survival rate of 0.23 was recorded for relocated black bears in Virginia compared to 0.87 for wild bears from Shenandoah National Park that were not relocated (Comly 1993). In GSMNP, a mortality rate of at least 19% (n = 341) was recorded for bears that were relocated (Stiver 1991). This percentage was likely higher because most relocated bears (56%) were never recovered and had unknown fates (Stiver 1991). In the current study, 9 bears that were initially released on-site were relocated because of continued nuisance activity. Of these 9 relocated bears, at least 2 died from legal hunting, whereas the remaining 7 had unknown fates. In comparison, 16% (n = 12) of the radio-collared bears released on-site that were not relocated died. Although recorded mortality rates of relocated bears and bears released on-site were similar in my study, mortality of relocated bears was likely higher.

Survival of females translocated in Virginia was 0.37 (Comly 1993) compared to 1.00 for females released on-site in GSMNP. The higher survival of females released on-site could have substantial management implications because of their contribution to population growth and sustainability through the production and rearing of young. Furthermore, relocation of adult females may result in a decline in their reproduction the following year (Miller and Ballard 1982, Brannon 1987). However, at least 4 females (#144, #162, #175, and #236) released on-site in GSMNP were documented as having cubs in subsequent years.

Males had a lower survival rate than females during the current study. This difference may be a result of home range size. Males in GSMNP have larger home ranges than females (Garshelis and Pelton 1981, Quigley 1982, Carr 1983, van Manen 1994) and are more likely to occupy areas outside the boundaries of the Park where mortality factors are greater. Six males (#248, #277, #291, #308, #319, and #1357) had home ranges that included areas outside GSMNP (Figure 6). Comparatively, no female bears had home ranges outside GSMNP (Figure 6).

Results from the survival analysis support my interpretation pertaining to differences between the sexes in the on-site release models. Males released on-site were less successful within the same year of release, but more successful in years following release. Therefore, the difference in success between the sexes in successive years may result from males not being available for recapture because of higher mortality.

Bear Locations vs. Release Sites

The results of the compositional analysis detected no difference between the distance zone compositions (P=0.31), therefore bear use of areas surrounding the release sites did not differ from random. If differences between distance zones had been detected and the distance zone closest to the release site (1 km) was ranked lowest in use, it may be evidence that bears were being displaced from habitats surrounding the release site. Thus, the results indicate that on-site releases do not displace a bear from using habitats in areas near the release sites.

Only 2 other studies pertaining to capture and on-site release on-site have addressed movements of bears in relation to their release sites. Wooding et al. (1988)

monitored 3 apiary-raiding bears in Florida that remained in the area of the release site. Shull (1994) monitored 15 males for 14 days after release and reported 71.7% of the radio locations within 4 km of the release site. In, comparison I recorded 59.6% of the radio locations within 4 km of the release site for the entire study period (Table 22).

Although the assumptions of compositional analysis were not violated in the analysis, interpretation of the results were limited. Home ranges of bears before being released on-site were not known. Thus, use of the term "displaced" was assuming home ranges of bears before capture included the area surrounding the release sites. This could result in interpretive biases, because some bears, such as dispersing subadult males, could have been passing through the area and encountered a developed site. Because no differences were detected among the distance zones, biases associated with this assumption were minimal.

Other factors also may have affected the results of this analysis. The sampling unit in compositional analysis is not the number of radio locations, but rather the number of radio tracked animals (Aebischer et al. 1993). However, the number of radio locations per animal determines the accuracy with which its use is estimated (Aebischer et al. 1993). The number of radio locations per bear (Table 21) may not have provided stable estimates of home range size which would have affected the proportion values in the analysis. Additionally, the proportion of males and females in the sample (n=14; males = 9, females = 5) could have created some bias in the analysis. Because male home ranges were larger than female home ranges, locations of males were more likely to be greater distances from a release site than locations of females because of the larger area of their home range. This could have caused more locations to occur in the buffer zone farthest away from the release site (>5 km) (Table 22). Although comparisons of use between sexes could have decreased this bias, comparisons would not have been valid because of sample sizes (Aebischer et al. 1993).

CHAPTER VI

MANAGEMENT IMPLICATIONS

The results of the short-term models demonstrated the importance of detecting and capturing nuisance bears early in their behavioral and habituation progression (i.e., when active in developed areas at night) to increase the probability of success for on-site releases. Learned behavior in bears, such as habituation and food conditioning to humans, can be changed by further learning, and early learning is the most effective (McCullough 1982). Thus, modification of nuisance behavior from aversive conditioning, such as capture and on-site release, is most effective when performed on bears encountering human foods for the first time (Gilbert 1989, McCullough 1982). The models indicated that on-site releases of night active bears were 3.4 (95% CI = 1.1 - 10.7) times less likely to require further management actions and 115.2 (95% CI = 11.2 - 1,185.7) times less likely to be relocated than day active bears. Furthermore, bears that were night active were 5.8 (95% CI = 1.0 - 33.0) times less likely to be relocated than bears that were active during crepuscular hours.

My results indicated that females and males were 5.6 (95% CI = 1.3-24.7) times less likely to require management actions at the release site within the same year than females with cubs. The model based on no relocation within the same year indicated that females were 20.1 (95% CI = 2.8-146.6) times less likely to be relocated than females with cubs or males. Females with cubs may be more difficult to deter from a developed area because of the extra nutritional stress associated with raising young (Mattson 1990, Riley et al. 1994) and the high-energy foods associated with the developed area.

Therefore, capturing nuisance females with cubs immediately after detection may decrease the likelihood of having to relocate family group.

Application of the models 1 (no observation at the release site within the same year) and 3 (no relocation from the release site within the same year) are limited because the population estimate used in the model is not available until the following year. Between 1990 and 1998, the population estimate ranged from 153 to 510 ($\bar{x}$ = 313) and had maximum annual increase and decrease of 146 and 132 bears, respectively (Table A.2). An increase in the population that is not accounted for in the models could overestimate the relative probability of success. For example, an increase of 146 bears in the population estimate would decrease the chances of success by a factor of 0.4 (95% CI = 0.2-0.9) for model 1 and a factor of 0.2 (95% CI = 0.0-0.5) for model 3. Likewise, an unaccounted decrease of 132 bears in the population would underestimate the relative success probability because the chances of success would be increased by a factor of 2.1 (95% CI = 1.1 - 4.0) for model 1 and 5.4 (95% CI = 1.9 – 15.7) for model 3. To compensate for the lack of the current year's population estimate, Park biologist could use a combination of data from the previous year to make an educated guess as to whether the population has increased, decreased, or remained stable. Errors associated with the predicted success probability as a result of an inaccurate population estimate would have a greater impact on management if it was overestimated. Therefore, I recommend using a conservative approach that is less likely to underestimate population size; this will decrease the probability that a release is predicted to be successful when it is actually a failure.

The concept of capture and on-site release for nuisance black bears is to create a negative stimulus that outweighs the positive rewards of entering a developed area and obtaining human foods. Results of the multiple variable models indicated that success of capture and release on-site within the same year of capture may be increased by: 1) monitoring campgrounds and picnic areas regularly at night to detect nuisance bears when they are night active, 2) capturing nuisance bears while they are night active, especially females with cubs, and 3) coordinating the frequency and effort of monitoring based on the estimated population increase or decrease from the previous year. Furthermore, the models could be applied by managers to determine the predicted probability of success and aid in the decision making process of when it is appropriate to use on-site releases.

Survival of bears released on-site did not seem to be negatively affected by on-site releases. The only mortality in my study resulted from legal hunting outside GSMNP. Furthermore, the results from the compositional analysis suggests that bears released on-site did not avoid areas in proximity to the release sites. If bears had avoided the areas surrounding the release sites, one could speculate that the on-site releases might have displaced bears into areas outside GSMNP where exposure to mortality is higher. Additionally, the high survival of females released on-site could have substantial management implications because of their contribution to the population through the production and rearing of young. Therefore, on-site releases of females may be a better management approach than relocation.

Capture and on-site release is a proactive approach to management of nuisance bears that focuses on detecting nuisance activity at an early stage and deterring further nuisance behavior. When compared to the more reactive management approach of relocation, this technique offers advantages to GSMNP biologists. On-site releases better maintain the social structure of the local population by allowing the offending bear to be released in the same area. Survival rates and success rates of bears released on-site seem to be higher than relocated bears in GSMNP. In the long term, on-site releases may reduce costs and maintain positive public relations because of the higher success rates.

Future research on capture and release on-site in GSMNP should focus on validating the multiple variable models with independent data, identification and methods to quantitatively measure additional factors that may contribute to the success on-site releases (e.g., soft mast), and the effectiveness of the technique on nuisance bears in the backcountry.

PART II

SURVIVAL OF ORPHANED BLACK BEARS RELEASED IN THE GREAT SMOKY MOUNTAINS

CHAPTER I

INTRODUCTION

Releasing orphaned bear cubs or yearlings into the wild is a recurring problem for many wildlife agencies (Stiver et al. 1997). Orphaned bears are often found when females abandon their dens because of anthropogenic disturbance or when they are killed in vehicular or hunting-related incidents. Several techniques have been used to release orphaned bears into the wild: adoption by a foster mother (Clarke et al. 1980, Alt and Beecham 1984, Carney and Vaughan 1987), reintroduction with the natural mother (Seibert et al., In press), release after a period of captivity (Alt and Beecham 1984), and placing cubs in artificial or selected den sites (Jonkel et al. 1980; J. Beecham, Idaho Fish and Game, personal communication). However, studies to evaluate the survival of released orphan bears are lacking.

The Appalachian Bear Center (ABC), located in Townsend, Tennessee, is a non-profit organization established to rehabilitate orphaned or injured black bears (*Ursus americanus*) for return the wild. Between October 1997 and June 1998, ABC received 10 orphaned cubs from the Tennessee Wildlife Resources Agency (TWRA) and 1 yearling from Great Smoky Mountains National Park (GSMNP) to be rehabilitated and released into the wild.

The objective of this study was to estimate survival of orphaned bears returned to the wild. Research was conducted in the Tellico Bear Reserve (TBR) (9,315 ha) and in the Cataloochee area of GSMNP. Both areas lie within the Unaka Mountain Range of the southern Blue Ridge Province. TBR is surrounded by the Tellico Ranger District (approximately 50,000 ha) of Cherokee National Forest. The Cataloochee area is located in the southeast quadrant of GSMNP and is surrounded by private lands and Pisgah National Forest to the south and east. Elevations range from 230 m to 1,668 m in TBR and from 866 m to 2,000 m in the Cataloochee area of GSMNP. Both areas are characterized by mountainous terrain with steep slopes, narrow valleys and coves, and fast flowing streams.

CHAPTER II

METHODS

Bears were rehabilitated in 2 outdoor enclosures at ABC designed to mimic a natural habitat setting. Each enclosure was 0.20 ha and contained numerous trees and an artificial stream that served as a water source. The enclosures were surrounded by a 3.05-m high chain link fence lined with 5 strands of high-tensile electric fencing and 2.44-m high blinds, which served as visual barriers. Bears were fed mostly natural foods. Acorns (*Quercus* spp.) and hickory nuts (*Carya* spp.) comprised about 60% of food items. Other food items included apples (18%), dry dog food (18%), and other fruits and rainbow trout (*Oncorhynchus mykiss*) (4%). Bears were fed from behind the blinds by throwing food items over the fence. This scattered the food items throughout the enclosures and forced bears to forage for their food.

When bears had gained sufficient weight to be released, they were captured from the enclosures with box traps. I immobilized the bears with a combination of ketamine hydrochloride (Ketaset, Burns Veterinary Supply, Inc., Farmers Branch, Texas) (200 mg/ml), xylazine hydrochloride (Rompun, Haver-Lockhart, Inc., Shawnee, Kansas) (100 mg/ml), and mepivicaine hydrochloride (Carbocaine V, Winthrop Lab., New York, N.Y.) (20 mg/ml) injected intramuscularly at a dosage rate of 1 ml/110 kg estimated body weight. A wetting agent (Artificial Tears, Maurry Biol. Co., Los Angeles, California) was applied to the eyes of each bear after immobilization to prevent desiccation. I weighed each bear to verify the minimum release weight of 19 kg (M. Pelton, University of Tennessee, Knoxville, personal communication). All bears were eartagged, tattooed on the upper lip and inner thigh, and measured to record morphometric data. I fitted each bear with a radio-collar equipped with an activity sensor and a mortality sensor with a 6-hour delay (Telonics Inc., Mesa, Arizona). Radio-collars were attached with a cotton spacer. Before transport, yohimbine (Lloyd laboratories, Shenandoah, Iowa) was administered intravenously as an antagonist for the xylazine hydrochloride. I released 10 bears into TBR and 1 bear into the Cataloochee area of GSMNP.

Bears were monitored by aerial and ground telemetry 2-3 times/month to estimate survival. The pulse rate of the radio signal was recorded to determine if the radio-collar was emitting a mortality signal. When a mortality signal was recorded, I retrieved the collar to determine the fate of the bear (i.e., mortality or dropped collar). I also recorded the first and last monitored date and the straight-line distance from the release site to location where the collar was retrieved. I backdated release dates to determine survival of bears to time interval t. I divided the postrelease days into 12 time intervals of 15 days for a total of 180 days. I recorded the censored date (i.e., the time interval a bear was removed from the number of bears at risk) at the time interval of the last recorded active signal.

I estimated survival by using the staggered entry Kaplan-Meier procedure (Pollock et al. 1989). Survival was estimated by

$$\hat{S}(t) = \Pi\left(\frac{1-d_j}{r_j}\right),$$

$$\frac{j}{a_j} < t$$

where $\hat{S}$ is estimated survival, a_j is a particular time of death, d_j is the number of bears that died at time a_j, r_j is the number of bears at risk at time a_j, , t is the time interval, and I am considering the product of all j terms for which $a_j <$ the time t. An estimate of variance (var) is:

$$\mathrm{var}\left[\hat{S}(t)\right] = \frac{[S(t)]^2[1-S(t)]}{r(t)}.$$

I recorded no mortalities of bears during the study, therefore an estimate of variance and 90% confidence intervals could not be calculated given the formula provided by Pollock et al. (1989). Therefore, I used an alternative method that considers the distribution of the number of bears that die annually, where the probability of a bear dying at time x equals P_x (x, 0 –11) (n = 11 cubs) (Martorello 1998). Therefore, the probability of 0 cubs dying equals $P_{(x=0)}$. By setting $\alpha = 0.1$, we have

$$P_{(x=0)} = P_L^{11} = 0.1,$$

where P_L^{11} equals the probability that 11 cubs live and solving for P_L as:

$$11 \; ln \; P_L = ln \; 0.1$$

$$ln \; P_L = (ln \; 0.1)/11$$

$$P_L = 0.81.$$

Assumptions of the Kaplan-Meier procedure are: 1) bears monitored for survival were sampled randomly, 2) survival times were independent for different bears, 3) capturing or radio-collaring did not influence future survival, 4) censoring mechanisms were random, and 5) newly radio-collared bears had the same survival function as previously radio-collared bears (Pollock et al. 1989).

CHAPTER III

RESULTS

Between September 1997 and June 1998, 11 orphaned bears were rehabilitated at ABC. Weights of bears were 9 - 18 kg ($\bar{x}$ = 10 kg) at time of arrival and 19 - 32 kg ($\bar{x}$ = 25 kg) at time of release. Rehabilitation time for bears ranged from 60 to 146 days ($\bar{x}$ = 94 days). Average weight gain of bears was 0.2 kg/day (range 0.1 – 0.4 kg/day) (Table 25).

Released bears were monitored for survival from January 1998 to October 1998. Of the 11 radio-collared bears, 7 dropped their collars and were censored at the time interval of the last recorded active signal, 1 collar was never retrieved (unknown fate), radio contact with 1 bear was lost (unknown fate), and 2 bears were still active and censored at the end of the study. Straight-line distance from release site to the dropped collar location ranged from 0.6 km to 34.9 km ($\bar{x}$ = 8.8) (Table 1). I documented no mortalities of bears in the study. Although I did receive 1 unconfirmed report of a small radio-collared bear approaching a campsite, there were no confirmed nuisance encounters involving released bears.

Because the fate of 2 bears was unknown, I performed 2 separate analyses to estimate minimum and maximum survival. The first analysis censored the 2 bears with unknown fates at the time interval of the last recorded active signal, and the second assumed these 2 bears as mortalities. Survival up to 180 days postrelease ranged from 0.77 (90% CI = 0.34 - 1.00) (Figure 1) to 1.00 (90% CI = 0.81 - 1.00).

Table 24. Characteristics of orphaned black bears rehabilitated and released into the Smoky Mountains of Tennessee, 1998.

Bear ID	Sex	Arrival weight (kg)	Release weight (kg)	Rehab time (days)	Weight gain rate (kg/day)	Radio days (min.)	Collar distance from release site (km)	Fate at time collar became inactive
ABC 08	M	42	156	95	1.2	160	3.4	Alive
ABC 09	M	48	106	146	0.4	233	—	Active
ABC 12	M	55	119	78	0.8	123	—	Unknown
ABC 14	F	37	130	134	0.7	58	8.8	Alive
ABC 15	F	57	99	72	0.6	64	0.9	Alive
ABC 17	F	59	139	62	1.3	123	5.0	Alive
ABC 18	F	51	154	60	1.7	123	34.9	Alive
ABC 19	F	26	90	122	0.5	225	—	Active
ABC 20	M	88	134	119	0.4	145	2.8	Alive
ABC 21	M	33	103	94	0.7	—	0.6	Alive
NPS 01	M	33	117	55	1.5	46	—	Unknown
Average		**48**	**122**	**94**	**0.9**	**130**	**8.8**	

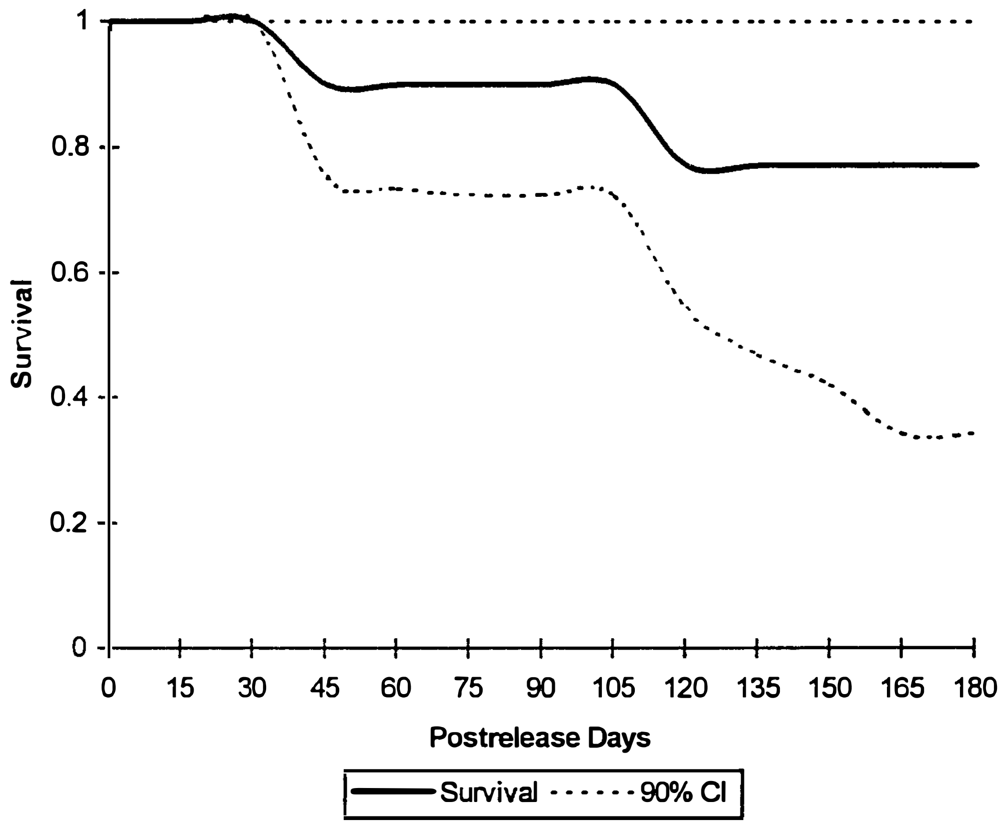


Figure 8. Minimum survival (95% CI) for orphaned black bears rehabilitated and released into the Smoky Mountains of Tennessee, 1998.

CHAPTER IV

DISCUSSION

Age of self-sufficiency for black bear cubs has been documented at 5.5 months (Erickson 1959) and to 6.5 months (Payne 1975). Brown bears (*U. arctos*) have demonstrated self-sufficiency at 7 months of age (Johnson and LeRoux 1973). Alt and Beecham (1984) reported successful releases with pen-reared cubs ≥5 months old. All cubs released in this study were between 12 and 20 months old. Therefore, survival likely was not negatively affected by the age of bears in my study.

Alt and Beecham (1984) considered releases successful if bears were recaptured in a non-nuisance situation after 30 days. Failure resulted if bears caused chronic nuisance problems or were found dead. Of 39 reintroduced bears, they documented 15 successes, 4 failures, and 20 unknown fates. Although our sample size in the current study was much smaller ($n = 11$), we were able to document success of releases with more certainty via radiotelemetry. During my study, I documented 10 bears alive >45 days and 7 bears alive >122 days. Therefore, based on the definition of successful releases by Alt and Beecham (1984), at least 10 of the 11 releases were successful.

Monitoring bears after release with radio telemetry also allowed me to calculate survival. Since no mortality was recorded, the maximum survival estimate was 1.00. The minimum survival estimate ($\hat{S} = 0.77$) represented the most conservative estimate possible, because the 2 bears with unknown fates were counted as mortalities during the time interval immediately following their last recorded active signal. Furthermore, censored bears were removed from the number at risk during the time interval immediately following their last recorded active signal. The minimum probability of survival to 120 days and 180 days postrelease was 0.90 (90% CI = 0.72 - 1.00) and 0.77 (90% CI = 0.34 – 1.00), respectively. These results could be important to bear managers in determining if rehabilitation and release of orphaned bears is feasible.

Short-term survival of bears in this study did not seem to be affected by the time of year that bears were released. Jonkel et al. (1980) recommended orphaned cubs achieve maximum weight gain in captivity and releasing them during the denning season or when natural foods are abundant. Furthermore, Alt and Beecham (1984) suggested that survival was increased in their study partly because of the availability of supplemental foods. In my study, 10 of 11 bears were received for rehabilitation in the fall and released in January or March. Although natural foods are usually not abundant during this time of year, the released bears likely had sufficient fat reserves to survive until early summer when soft mast would become available. Although bears released in January might den through the remainder of the winter months, I was unable to confirm any denning activity.

CHAPTER V

MANAGEMENT IMPLICATIONS

Rehabilitation and release of orphaned bears into the wild may offer a valuable management alternative. Historically, orphaned bears had to be destroyed, sent to zoos and other captive facilities, or fostered to adult females with cubs that were radio-collared for research (Jonkel et al. 1980). However, if rehabilitated and released orphan bears had a low probability of survival in the first couple of months after release, the cost and effort of rehabilitating a small number of bears may not be attractive to managers. My results indicate the short-term survival (up to 180 days) of rehabilitated and released orphan bears is possible. Thus, rehabilitation and release of orphan bears can be successful and may be a viable alternative to managers.

Long-term survival was not evaluated in my study and may have implications concerning the contribution of the released bears to the wild population. For example, 5 females were rehabilitated and released in my study. If the probability of survival to reproductive maturity (≥ 3.5 years old) for these females was greater than 0.50, their potential contribution to the population in the form of producing and rearing young could be substantial. This is particularly true if they survive to produce multiple litters. Future studies evaluating orphan bear releases should focus on long-term survival and reproductive contribution to local populations and the influence of rehabilitation methods on survival of bears after release. The rehabilitation and release of orphan bears may have implications and uses concerning the augmentation of small bear populations or repatriation into former ranges (Stiver et al. 1997). It also may serve as a management alternative for threatened or endangered bear species (Jonkel et al. 1980, Alt and Beecham 1984).

SUMMARY

1. Since 1990, wildlife biologists in GSMNP have used capture and on-site release as the primary management technique for nuisance black bears. This technique involves capturing and immobilizing bears that frequent developed areas, collecting biological data, and releasing the bears back into the same area. The premise of on-site releases is to reinforce the natural fear of humans that bears exhibit and thereby reduce the likelihood of return to the problem area. Although success of on-site releases has been reported in other studies, it has not been thoroughly documented in GSMNP. My objectives in Part I were to identify correlates of success for on-site releases, estimate survival, and evaluate movements in relation to release sites for black bears in GSMNP.

2. Between 1997-1998, I monitored human use areas of GSMNP for nuisance bear activity. I captured and on-site released 28 bears (16males, 12 females) a total of 30 times. Bears were released in picnic areas (*n* = 14), backcountry campsites (*n* = 10), campgrounds (*n* = 2), parking lots (*n* = 1), and roadsides (*n* = 1). Nine of the 28 bears (32%) were relocated as a result of continued nuisance activity.

3. I radio-collared and monitored 25 bears released on-site and recorded 570 telemetry locations.

4. I defined the overall success rate of on-site releases as the total number of bears released that were not relocated within the same year divided by the total number of bears released on-site. Between 1990-1998, 63 bears (44 males, 13 females, and 11 females with young) were released on-site in frontcountry areas of GSMNP a total of 85

times. The overall success rate for bears released on-site in frontcountry areas of GSMNP was 74% (n = 85).

5. I used data from 1990-1998 to develop multiple variable logistic regression models to identify correlates of success for on-site releases in frontcountry areas of GSMNP. I used fates of bears after release to define success and classified each on-site release as a success or failure according to 6 different definitions of success based on post release observations or management actions at the release site within the same year or in successive years. Independent variables used in the models included previous releases on-site, sex and family group size, age, release season, time of nuisance activity, capture area, population estimate for the year of capture, behavior, and total oak score from the fall prior to capture. I used up to 85 on-site releases to develop the models for the 6 success definitions.

6. The model for no observations at the release site within the same year as on-site release (success definition 1) indicated that population size, time of nuisance activity, and area of nuisance activity were important variables in determining success. Negative relationships were identified for bears that were day active in campgrounds or picnic areas in years of higher population abundance. The model fit the data and explained 48% of the variation.

7. The model for no management action necessary at the release site within the same year as on-site release (success definition 2) indicated that time of nuisance activity, area of nuisance activity, and sex and family group size were important variables in determining success. Negative relationships were identified for females with young that

were day active in picnic areas. The model exhibited a good fit to the data and explained 20% of the variation.

8. The model for no relocation necessary from the release site within the same year as on-site release (success definition 3) indicated that sex, time of nuisance activity, and population size were important variables. Negative relationships were identified for females that were day active in years of higher population abundance. The model fit the data and explained 50% of the likelihood.

9. The models that evaluated success of on-site releases in successive years (success definitions 4, 5, and 6) were best explained by the variable sex. A negative relationship with females was identified for the models based on no observations (success definition 4) and no management action necessary (success definition 5) at the release site in successive years. A negative relationship for the model based on no relocation necessary from the release site in successive years (success definition 6) was identified with females and females with young. The successive year models explained 35%, 27% and 35% of the likelihood for success definitions 4, 5, and 6, respectively. Goodness-of-fit statistics could not be calculated for any of the 3 successive year models.

10. Reliability of the 6 multiple variable models ranged from 0.68 to 0.83. The model for no relocation from the release site within the same year (success definition 3) exhibited the best predictive qualities by having the highest reliability value (0.83) of all the models.

11. The multiple variable models for success of on-site releases within the same year of capture (success defintions 1, 2, and 3) suggested that success could be increased by monitoring campgrounds and picnic areas regularly at night to detect nuisance bears

when they are night active, capturing nuisance bears while they are night active, and coordinating the frequency and effort of monitoring based on the estimated population increase or decrease from the previous year.

12. I used results from the multiple variable models to quantify success of on-site releases in GSMNP. I calculated relative success probabilities for all possible combinations of variables for success definitions 1, 2, and 3. Relative success probabilities ranged from 0.06 – 0.96 ($\bar{x}$ = 0.47) for success definition 1, 0.11 – 0.88 ($\bar{x}$ = 0.32) for success definition 2, and 0 – 0.96 ($\bar{x}$ = 0.30) for success definition 3.

13. I monitored 23 radio-collared bears (12 males, 11 females) to estimate survival. Of the 12 radio-collared males, 3 were relocated and censored, 2 were harvested by hunters, and 7 were active and censored at the end of the study. Of the 11 radio-collared females, 6 were relocated and censored, and 5 were active and censored at the end of the study.

14. I estimated survival of bears released on-site using the Kaplan-Meier staggered entry procedure. Survival during the entire study period for all bears was 0.71. Annual survival was 0.71 in 1997 and 1.00 in 1998, and the survival functions did not differ 9 ($P = 0.11$). Survival for male and female bears during the entire study was 0.50 and 1.00, respectively, and the survival functions did not differ ($P = 0.22$). Survival of bears released on-site in this study was higher compared to other studies that have evaluated survival of relocated bears.

15. I calculated 95% minimum convex polygons for 14 bears (9 males, 5 females) released on-site. Home ranges ranged from 3.3 km^2 to 272.9 km^2 ($\bar{x}$ = 62.1 km^2).

16. I used compositional analysis to examine the relationship of locations of bears released on-site with the release sites. I used telemetry data from 14 bears and created distance zones of 1 km, 2 km, 3 km, 4 km, 5 km, and >5 km around each release site to perform the analysis. The distance zone >5 km from the release site had the greatest proportional composition for home range area and number of locations within each zone. However, bear use between distance zones surrounding the release sites did not differ, and rank scores were ignored. This suggested that bears released on-site were neither avoiding nor attracted to the area of the release sites.

17. Future research on capture and on-site release in GSMNP should focus on validating the multiple variable models from my study with independent data, identification and methods to quantitatively measure additional factors that may contribute to the success on-site releases (e.g., soft mast), and the effectiveness of the technique on nuisance bears in the backcountry.

18. The results from this study indicate that capture and on-site release is a viable management alternative for biologists in GSMNP. The technique better meets the objective for bear management in the Park because it requires biologists to take a proactive approach to management and allows bears to remain in GSMNP as a continued resource.

19. Releasing orphaned bear cubs or yearlings into the wild is a recurring problem among many wildlife agencies. Studies to evaluate the survival of released orphan bears are lacking. If rehabilitated and released orphan bears had a low chance of survival in the first couple of months after release, the cost and effort of rehabilitating a small number of bears may not be attractive to managers responsible for managing large populations. The

objective of the research in Part II was estimate survival of rehabilitated orphaned bears that were released into the Smoky Mountains.

20. Between October 1997 and June 1998, the Appalachian Bear Center (ABC) in Townsend, Tennessee, received 10 orphaned cubs from the Tennessee Wildlife Resources Agency and 1 yearling from GSMNP to be rehabilitated and released. After reaching a minimum release weight of 19 kg, 10 bears were released into the Tellico Bear Reserve between January 1998 and March 1998, and 1 bear was released in the Cataloochee area of GSMNP in July 1998.

21. I monitored released orphaned bears by aerial and ground telemetry 2-3 times/month from January 1998 to October 1998 to estimate survival. Of the 11 radio-collared bears, 7 dropped their collars and were censored at the time interval of the last recorded active signal, 1 collar was never retrieved (unknown fate), 1 bear was lost (unknown fate), and 2 bears were still active at the end of the study. I recorded no confirmed mortalities of released bears in the study.

22. Because the fate of 2 bears in the study was unknown, I performed 2 separate analyses to estimate minimum and maximum survival. I estimated survival by using the Kaplan-Meier staggered entry procedure and backdated release dates to determine survival of bears by postrelease days. Survival up to 180 days postrelease ranged from 0.77 (minimum) to 1.00 (maximum).

23. Rehabilitation and release of orphaned bears into the wild offers a management alternative for black bear managers. My results indicated that short-term survival (up to 180 days) of rehabilitated and released orphan bears is possible. Thus,

rehabilitation and release of orphan bears can be successful and may be a viable alternative to managers.

24. Future studies evaluating orphan bear releases should focus on long term survival and reproductive contribution to local populations and the influence of rehabilitation methods on survival of bears after release.

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APPENDICES

Appendix A. Summary of data used for logistic regression models.

Table A.1. Classifications of successes and failures related to on-site releases of nuisance black bears in Great Smoky Mountains National Park, 1990-98.

Bear ID	Capture Date	Fate[a]	Success Definition[b] 1	2	3	4	5	6
139	11/11/90	1	1	1	1	1	1	1
141	05/29/91	7	1	1	1	1	1	1
144	06/27/91	1	1	1	1	2	2	2
146	08/29/91	1	1	1	1	1	1	1
147	10/01/91	1	1	1	1	1	1	1
148	10/24/91	7	1	1	1	1	1	1
149	05/13/92	4	2	2	2	.	.	.
150	05/14/92	1	1	1	1	1	1	1
124	06/06/92	2	2	2	2	.	.	.
125	06/06/92	1	1	1	1	1	1	1
151	06/08/92	4	2	2	1	1	1	1
152	06/12/92	2	2	2	2	.	.	.
157	06/19/92	1	1	1	1	.	.	.
158	06/19/92	2	2	2	2	.	.	.
1079	06/21/92	7	1	1	1	.	.	.
160	06/23/92	1	1	1	1	1	1	1
162	06/23/92	1	1	1	1	2	2	2
163	06/24/92	2	2	2	2	.	.	.
151	06/25/92	1	1	1	1	1	1	1
161	06/27/92	4	2	2	1	1	1	1
168	06/30/92	4	2	2	1	1	1	1
172	07/02/92	2	2	2	2	.	.	.

Table A.1. (Continued).

Bear ID	Capture Date	Fate[a]	Success Definition[b] 1	2	3	4	5	6
173	07/04/92	1	1	1	1	1	1	1
174	07/14/92	1	1	1	1	2	2	1
175	07/15/92	1	1	1	1	2	2	2
161	07/21/92	1	1	1	1	1	1	1
184	08/04/92	2	2	2	2	.	.	.
168	08/09/92	1	1	1	1	1	1	1
149	08/10/92	2	2	2	2	.	.	.
203	05/20/93	6	2	1	1	1	1	1
204	05/25/93	1	1	1	1	2	2	1
205	05/27/93	2	2	2	2	.	.	.
207	06/02/93	1	1	1	1	1	1	1
208	06/06/93	1	1	1	1	1	1	1
210	06/19/93	4	2	2	1	2	2	2
210	08/15/93	1	1	1	1	2	2	2
211	12/04/93	3	1	1	1	.	.	.
215	05/29/94	6	2	1	1	1	1	1
203	06/08/94	2	2	2	2	.	.	.
218	06/15/94	1	1	1	1	1	1	1
204	06/17/94	1	1	1	1	2	2	1
162	06/30/94	2	2	2	2	.	.	.
174	08/15/94	1	1	1	1	1	1	1
225	10/20/94	1	1	1	1	1	1	1
1216	05/10/95	2	2	2	2	.	.	.

Table A.1. (Continued).

Bear ID	Capture Date	Fate[a]	Success Definition[b] 1	2	3	4	5	6
204	05/11/95	4	2	2	1	.	.	.
227	06/28/95	1	1	1	1	1	1	1
228	07/04/95	1	1	1	1	1	1	1
175	07/08/95	1	1	1	1	2	2	2
235	07/12/95	1	1	1	1	1	1	1
236	07/19/95	4	2	2	1	2	2	1
236	07/24/95	4	2	2	1	2	2	1
144	07/28/95	4	2	2	1	2	2	2
204	07/28/95	1	1	1	1	.	.	.
236	07/30/95	1	1	1	1	2	2	1
237	08/04/95	2	2	2	2	.	.	.
231	08/09/95	1	1	1	1	1	1	1
246	08/18/95	1	1	1	1	1	1	1
144	09/05/95	1	1	1	1	2	2	2
259	08/13/96	1	1	1	1	1	1	1
236	08/19/96	1	1	1	1	2	2	1
261	08/19/96	1	1	1	1	1	1	1
265	08/25/96	1	1	1	1	1	1	1
248	05/20/97	1	2	1	1	1	1	1
277	06/05/97	7	1	1	1	.	.	.
1357	06/12/97	4	2	2	1	.	.	.
285	06/27/97	2	2	2	2	.	.	.
1357	06/30/97	7	1	1	1	.	.	.

Table A.1. (Continued).

Bear ID	Capture Date	Fate[a]	Success Definition[b] 1	2	3	4	5	6
175	07/03/97	4	2	2	2	.	.	.
287	07/03/97	2	2	2	2	.	.	.
288	07/06/97	6	2	1	1	2	1	1
291	07/15/97	1	1	1	1	1	1	1
175	07/17/97	2	2	2	2	.	.	.
1339	07/22/97	2	2	2	2	.	.	.
284	07/28/97	1	1	1	1	1	1	1
144	08/05/97	2	2	2	2	.	.	.
294	08/07/97	2	2	2	2	.	.	.
296	08/11/97	2	2	2	2	.	.	.
236	06/18/98	1	1	1	1	.	.	.
319	06/24/98	1	1	1	1	.	.	.
322	06/26/98	1	1	1	1	.	.	.
303	07/18/98	2	2	2	2	.	.	.
325	08/05/98	1	1	1	1	.	.	.

[a]Fate: 1 = unknown/free ranging; 2 = relocated from release site; 3 = relocated from site different than release site; 4 = captured and released on-site from initial release site; 5 = captured and released on-site from site different than initial release site; 6 = caused problems at the release site but never recaptured; 7 = roadkill; 8 = hunter kill; 9 = caused problems at site other than release site but not recaptured.
[b]1 = success, 2 = failure

Table A.2. Independent variables used to identify correlates of success for nuisance black bears captured and on-site released in Great Smoky Mountains National Park, 1990-98.

Bear ID	Date	Sex/family group	Age	CROS1[a]	CROS2[b]	Capture Area	Time of Activity	Behavior	Release Season	Population Estimate[c]	Total Oak Index[d]
139	11/11/90	female w/cubs	7.5	0	0	other	day	bold	fall/winter	206.89	3.03
141	05/29/91	male	5.5	0	0	picnic area	night	shy	spring	241.18	2.52
144	06/27/91	female	1.5	0	0	picnic area	day	bold	summer	241.18	2.52
146	08/29/91	male	5.5	0	0	other	night	shy	summer	241.18	2.52
147	10/01/91	male	-	0	0	other	night	shy	fall/winter	241.18	2.52
148	10/24/91	male	3.5	0	0	other	night	shy	fall/winter	241.18	2.52
149	05/13/92	male	4.5	0	0	picnic area	crepuscular	shy	spring	240.96	1.49
150	05/14/92	male	8.5	0	0	other	night	shy	spring	240.96	1.49
124	06/06/92	female w/cubs	7.5	0	0	campground	day	bold	summer	240.96	1.49
125	06/06/92	male	2.5	0	0	campground	crepuscular	bold	summer	240.96	1.49
151	06/08/92	male	6.5	0	0	picnic area	night	shy	summer	240.96	1.49
152	06/12/92	male	4.5	0	0	picnic area	day	bold	summer	240.96	1.49
157	06/19/92	female w/cubs	5.5	0	0	picnic area	day	bold	summer	240.96	1.49
158	06/19/92	male	2.5	0	0	other	day	bold	summer	240.96	1.49
1079	06/21/92	male	6.5	0	0	picnic area	night	shy	summer	240.96	1.49
160	06/23/92	male	4.5	0	0	picnic area	night	shy	summer	240.96	1.49
162	06/23/92	female	7.5	0	0	campground	day	bold	summer	240.96	1.49
163	06/24/92	male	1.5	0	0	other	day	bold	summer	240.96	1.49
151	06/25/92	male	6.5	1	0	picnic area	night	shy	summer	240.96	1.49
161	06/27/92	male	6.5	0	0	picnic area	crepuscular	bold	summer	240.96	1.49
168	06/30/92	male	3.5	0	0	picnic area	night	shy	summer	240.96	1.49
172	07/02/92	male	5.5	0	0	campground	day	bold	summer	240.96	1.49
173	07/04/92	female	5.5	0	0	other	day	shy	summer	240.96	1.49
174	07/14/92	male	3.5	0	0	picnic area	night	shy	summer	240.96	1.49
175	07/15/92	female	6.5	0	0	picnic area	night	shy	summer	240.96	1.49
161	07/21/92	male	6.5	1	0	picnic area	crepuscular	bold	summer	240.96	1.49

Table A.2. (Continued).

Bear ID	Date	Sex/family group	Age	CROS1[a]	CROS2[b]	Capture Area	Time of Activity	Behavior	Release Season	Population Estimate[c]	Total Oak Index[d]
184	08/04/92	female w/cubs	5.5	0	0	picnic area	day	bold	summer	240.96	1.49
168	08/09/92	male	3.5	1	0	picnic area	night	shy	summer	240.96	1.49
149	08/10/92	male	4.5	1	0	picnic area	day	bold	summer	240.96	1.49
203	05/20/93	male	1.5	0	0	picnic area	day	shy	spring	152.96	1.88
204	05/25/93	male	7.5	0	0	picnic area	night	shy	spring	152.96	1.88
205	05/27/93	male	1.5	0	0	picnic area	day	bold	spring	152.96	1.88
207	06/02/93	male	1.5	0	0	picnic area	crepuscular	shy	summer	152.96	1.88
208	06/06/93	male	2.5	0	0	picnic area	day	shy	summer	152.96	1.88
210	06/19/93	female	6.5	0	0	campground	night	shy	summer	152.96	1.88
210	08/15/93	male	6.5	1	0	campground	night	bold	summer	152.96	1.88
211	12/04/93	male	2.5	0	0	other	night	shy	fall/winter	152.96	1.88
215	05/29/94	male	3.5	0	0	campground	day	bold	spring	298.64	2.19
203	06/08/94	male	2.5	0	1	picnic area	crepuscular	shy	summer	298.64	2.19
218	06/15/94	male	7.5	0	0	picnic area	night	shy	summer	298.64	2.19
204	06/17/94	male	8.5	0	1	picnic area	night	shy	summer	298.64	2.19
162	06/30/94	female w/cubs	9.5	0	1	campground	day	bold	summer	298.64	2.19
174	08/15/94	male	5.5	0	1	picnic area	crepuscular		summer	298.64	2.19
225	10/20/94	male	7.5	0	0	other	night	shy	fall/winter	298.64	2.19
1216	05/10/95	male	3.5	0	0	picnic area	night	shy	spring	404.72	2.04
204	05/11/95	male	9.5	0	2	picnic area	night	shy	spring	404.72	2.04
1152	05/26/95	male	10.5	0	0	picnic area	night	shy	spring	404.72	2.04
223	05/31/95	female	4.5	0	0	other	night	shy	spring	404.72	2.04
227	06/28/95	male	3.5	0	0	picnic area	crepuscular	shy	summer	404.72	2.04
228	07/04/95	male	4.5	0	0	picnic area	night	shy	summer	404.72	2.04
175	07/08/95	female w/cubs	9.5	0	1	picnic area	crepuscular	bold	summer	404.72	2.04
235	07/12/95	female	4.5	0	0	picnic area	crepuscular	shy	summer	404.72	2.04

Table A.2. (Continued).

Bear ID	Date	Sex/family group	Age	CROS1[a]	CROS2[b]	Capture Area	Time of Activity	Behavior	Release Season	Population Estimate[c]	Total Oak Index[d]
236	07/19/95	female	6.5	0	0	picnic area	crepuscular	shy	summer	404.72	2.04
236	07/24/95	female	6.5	1	0	picnic area	crepuscular	shy	summer	404.72	2.04
144	07/28/95	female	5.5	0	1	picnic area	night	shy	summer	404.72	2.04
204	07/28/95	male	9.5	1	2	picnic area	crepuscular	shy	summer	404.72	2.04
236	07/30/95	female	6.5	2	0	picnic area	crepuscular	shy	summer	404.72	2.04
237	08/04/95	female	9.5	0	0	picnic area	day	bold	summer	404.72	2.04
231	08/09/95	female	6.5	0	0	other	crepuscular	shy	summer	404.72	2.04
246	08/18/95	male	9.5	0	0	picnic area	night	shy	summer	404.72	2.04
144	09/05/95	female	5.5	1	1	picnic area	crepuscular	shy	fall/winter	404.72	2.04
259	08/13/96	male	3.5	0	0	picnic area	night	shy	summer	385.78	3.63
236	08/19/96	female	7.5	0	3	picnic area	crepuscular	bold	summer	385.78	3.63
261	08/19/96	male	6.5	0	0	campground	night	shy	summer	385.78	3.63
265	08/25/96	female	3.5	0	0	other	day	bold	summer	385.78	3.63
248	05/20/97	male	2.5	0	0	picnic area	crepuscular	bold	spring	509.67	2.94
277	06/05/97	male	2.5	0	0	picnic area	night	shy	summer	509.67	2.94
1357	06/12/97	male	3.5	0	0	picnic area	night	shy	summer	509.67	2.94
285	06/27/97	male	5.5	0	0	picnic area	day	bold	summer	509.67	2.94
1357	06/30/97	male	3.5	1	0	picnic area	night	shy	summer	509.67	2.94
175	07/03/97	female w/cubs	11.5	0	2	picnic area	night	shy	summer	509.67	2.94
287	07/03/97	female w/cubs	8.5	0	0	picnic area	crepuscular	shy	summer	509.67	2.94
288	07/06/97	female	8.5	0	0	picnic area	crepuscular	shy	summer	509.67	2.94
291	07/15/97	male	4.5	0	0	picnic area	night	shy	summer	509.67	2.94
175	07/17/97	female w/cubs	11.5	1	2	picnic area	night	shy	summer	509.67	2.94
1339	07/22/97	male	2.5	0	0	picnic area	night	shy	summer	509.67	2.94
284	07/28/97	male	9.5	0	0	picnic area	night	shy	summer	509.67	2.94
144	08/05/97	female w/cubs	7.5	0	3	picnic area	crepuscular	bold	summer	509.67	2.94

Table A.2. (Continued).

Bear ID	Date	Sex/family group	Age	CROS1[a]	CROS2[b]	Capture Area	Time of Activity	Behavior	Release Season	Population Estimate[c]	Total Oak Index[d]
294	08/07/97	female	3.5	0	0	picnic area	crepuscular	shy	summer	509.67	2.94
296	08/11/97	female w/cubs	5.5	0	0	campground	crepuscular	bold	summer	509.67	2.94
236	06/18/98	female	9.5	0	4	picnic area	night	shy	summer	377.53	1.98
319	06/24/98	male	2.5	0	0	campground	night	bold	summer	377.53	1.98
322	06/26/98	male	4.5	0	0	other	crepuscular	bold	summer	377.53	1.98
303	07/18/98	male	3.5	0	0	picnic area	day	bold	summer	377.53	1.98
325	08/05/98	female	4.5	0	0	other	day	bold	summer	377.53	1.98

[a]Previous releases on-site within the same year.
[b]Previous releases on-site in years prior to current on-site release.
[c]Population estimate of Tennessee study area in Great Smoky Mountains National Park (University of Tennessee, unpublished data).
[d]Hard mast survey score for Great Smoky Mountains National Park from year prior to on-site release (National Park Service, unpublished data).

Appendix B. Predicted probabilities success for on-site releases

Table B.1. Predicted probability of success for on-site releases of nuisance black bears in Great Smoky Mountains National Park for all scenarios of model 1 (no observations at the release site within the same year).

Variables			
Time of nuisance activity	**Capture Area**	**Population estimate**	**Predicted probability of success**
Day active	Campground	510	0.060
Crepuscular/Night active	Campground	510	0.399
Day active	Picnic area	510	0.068
Crepuscular/Night active	Picnic area	510	0.431
Day active	Other area	510	0.431
Crepuscular/Night active	Other area	510	0.887
Day active	Campground	313	0.163
Crepuscular/Night active	Campground	313	0.669
Day active	Picnic area	313	0.181
Crepuscular/Night active	Picnic area	313	0.697
Day active	Other area	313	0.697
Crepuscular/Night active	Other area	313	0.960

Table B.2. Predicted probability of success for on-site releases of nuisance black bears in Great Smoky Mountains National Park for all scenarios of model 2 (no management action necessary at the release site within the same year).

Variables			
Time of nuisance activity	**Capture Area**	**Sex**	**Predicted probability of success**
Day active	Campground/Other	Male/Female	0.674
Crepuscular/Night active	Campground/Other	Male/Female	0.875
Day active	Picnic area	Male/Female	0.399
Crepuscular/Night active	Picnic area	Male/Female	0.692
Day active	Picnic area	Female w/cubs	0.106
Crepuscular/Night active	Picnic area	Female w/cubs	0.286
Crepuscular/Night active	Campground/Other	Female w/cubs	0.554
Day active	Campground/Other	Female w/cubs	0.269

Table B.3. Predicted probability of success for on-site releases of nuisance black bears in Great Smoky Mountains National Park for all scenarios of model 3 (no relocation from the release site within the same year).

Variables			
Time of nuisance activity	**Sex**	**Population estimate**	**Predicted probability of success**
Day	Female	510	0.016
Crepuscular	Female	510	0.241
Night	Female	510	0.650
Day	Male/Female with cubs	510	0.001
Crepuscular	Male/Female with cubs	510	0.015
Night	Male/Female with cubs	510	0.084
Day	Female	313	0.167
Crepuscular	Female	313	0.798
Night	Female	313	0.959
Day	Male/Female with cubs	313	0.010
Crepuscular	Male/Female with cubs	313	0.164
Night	Male/Female with cubs	313	0.534

Appendix C. Survival statistics of black bears captured and on-site released.

Table C.1. Survival of nuisance black bears released on-site in Great Smoky Mountains National Park, 1997-98.

Month	No. at risk	No. added	No. censored	No. deaths	Survival	Mortality	Variance (survival)	95% CI Lower	95% CI Upper
1997									
May	0	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Jun	1	3	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Jul	4	6	2	0	1.0000	0.0000	0.0000	1.0000	1.0000
Aug	8	3	4	0	1.0000	0.0000	0.0000	1.0000	1.0000
Sep	7	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Oct	7	0	2	2	0.7143	0.2857	0.0208	0.4314	0.9971
Nov	3	0	0	0	0.7143	0.0000	0.0486	0.2822	1.0000
Dec	3	0	0	0	0.7143	0.0000	0.0486	0.2822	1.0000
1998									
Jan	3	0	0	0	0.7143	0.0000	0.0486	0.2822	1.0000
Feb	3	0	0	0	0.7143	0.0000	0.0486	0.2822	1.0000
Mar	3	0	0	0	0.7143	0.0000	0.0486	0.2822	1.0000
Apr	3	0	0	0	0.7143	0.0000	0.0486	0.2822	1.0000
May	3	3	0	0	0.7143	0.0000	0.0486	0.2822	1.0000
Jun	6	4	0	0	0.7143	0.0000	0.0243	0.4088	1.0000
Jul	10	1	1	0	0.7143	0.0000	0.0146	0.4776	0.9509
Aug	10	2	0	0	0.7143	0.0000	0.0146	0.4776	0.9509
Sep	12	0	0	0	0.7143	0.0000	0.0121	0.4983	0.9303
Oct	12	0	0	0	0.7143	0.0000	0.0121	0.4983	0.9303
Nov	12	0	0	0	0.7143	0.0000	0.0121	0.4983	0.9303
Dec	12	0	12	0	0.7143	0.0000	0.0121	0.4983	0.9303
TOTAL		**23**	**21**	**2**					

Table C.2. Annual survival of nuisance black bears released on-site in Great Smoky Mountains National Park, 1997 and 1998.

Month	No. at risk	No. added	No. censored	No. deaths	Survival	Mortality	Variance (survival)	95% CI Lower	95% CI Upper
1997									
May	0	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Jun	1	3	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Jul	4	6	2	0	1.0000	0.0000	0.0000	1.0000	1.0000
Aug	8	3	4	0	1.0000	0.0000	0.0000	1.0000	1.0000
Sep	7	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Oct	7	0	2	2	0.7143	0.2857	0.0208	0.4314	0.9971
Nov	3	0	0	0	0.7143	0.0000	0.0486	0.2822	1.0000
Dec	3	0	3	0	0.7143	0.0000	0.0486	0.2822	1.0000
TOTAL		13	11	2					

Month	No. at risk	No. added	No. censored	No. deaths	Survival	Mortality	Variance (survival)	95% CI Lower	95% CI Upper	Contingency Table $E(d_{1j})$[a]	$Var_1(d_{1j})$[b]	$Var_2(d_{1j})$[c]
1998												
May	0	3	0	0	1.0000	0.0000	0.0000	0.74	1.0000	0.000	0.000	0.000
Jun	3	4	0	0	1.0000	0.0000	0.0000	0.74	1.0000	0.000	0.000	0.000
Jul	7	1	1	0	1.0000	0.0000	0.0000	0.74	1.0000	0.000	0.000	0.000
Aug	7	2	0	0	1.0000	0.0000	0.0000	0.74	1.0000	0.000	0.000	0.000
Sep	9	0	0	0	1.0000	0.0000	0.0000	0.74	1.0000	0.000	0.000	0.000
Oct	9	0	0	0	1.0000	0.0000	0.0000	0.74	1.0000	1.125	0.492	0.459
Nov	9	0	0	0	1.0000	0.0000	0.0000	0.74	1.0000	0.000	0.000	0.000
Dec	9	0	9	0	1.0000	0.0000	0.0000	0.74	1.0000	0.000	0.000	0.000
										1.250	0.492	0.459
TOTAL		10	10	0						Chi-square =	2.571	2.755
											$P = 0.11$	

[a] $E(d_{1j}) = d_j r_{1j}/r_j$ (Pollock et al. 1989)
[b] $var_1(d_{1j}) = d_j r_{01}(r_j - d_j)/r_j^2(r_j - 1)$ (Pollock et al. 1989)
[c] $var_2(d_{1j}) = r_{0j} r_{1j} d_j / r_j^2$ (Pollock et al. 1989)

Table C.3. Survival of male and female nuisance black bears released on-site in Great Smoky Mountains National Park, 1997 and 1998.

Month	No. at risk	No. added	No. censored	No. deaths	Survival	Mortality	Variance (survival)	95% CI Lower	95% CI Upper
MALE									
1997									
May	0	1	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Jun	1	3	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Jul	4	2	1	0	1.0000	0.0000	0.0000	1.0000	1.0000
Aug	5	0	1	0	1.0000	0.0000	0.0000	1.0000	1.0000
Sep	4	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
Oct	4	0	0	2	0.5000	0.5000	0.0313	0.1535	0.8465
Nov	2	0	0	0	0.5000	0.0000	0.0625	0.0100	0.9900
Dec	2	0	0	0	0.5000	0.0000	0.0625	0.0100	0.9900
1998									
Jan	2	0	0	0	0.5000	0.0000	0.0625	0.0100	0.9900
Feb	2	0	0	0	0.5000	0.0000	0.0625	0.0100	0.9900
Mar	2	0	0	0	0.5000	0.0000	0.0625	0.0100	0.9900
Apr	2	0	0	0	0.5000	0.0000	0.0625	0.0100	0.9900
May	2	3	0	0	0.5000	0.0000	0.0625	0.0100	0.9900
Jun	5	2	0	0	0.5000	0.0000	0.0250	0.1901	0.8099
Jul	7	1	1	0	0.5000	0.0000	0.0179	0.2381	0.7619
Aug	7	0	0	0	0.5000	0.0000	0.0179	0.2381	0.7619
Sep	7	0	0	0	0.5000	0.0000	0.0179	0.2381	0.7619
Oct	7	0	0	0	0.5000	0.0000	0.0179	0.2381	0.7619
Nov	7	0	0	0	0.5000	0.0000	0.0179	0.2381	0.7619
Dec	7	0	7	0	0.5000	0.0000	0.0179	0.2381	0.7619
TOTAL		12	10	2					

Table C.3. (Continued)

Month	No. at risk	No. added	No. censored	No. deaths	Survival	Mortality	Variance (survival)	95% CI Lower	95% CI Upper	Contingency Table $E(d_{1j})$[a]	$Var_1(d_{1j})$[b]	$Var_2(d_{1j})$[c]
FEMALE												
1997												
May	0	0	0	0	-	-	-	-	-	-	-	-
Jun	0	0	0	0	-	-	-	-	-	-	-	-
Jul	0	4	1	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Aug	3	3	3	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Sep	3	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Oct	3	0	2	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.857	0.490	0.408
Nov	1	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Dec	1	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
1998												
Jan	1	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Feb	1	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Mar	1	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Apr	1	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
May	1	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Jun	1	2	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Jul	3	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Aug	3	2	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Sep	5	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Oct	5	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Nov	5	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
Dec	5	0	5	0	1.0000	0.0000	0.0000	0.7616	1.0000	0.000	0.000	0.000
										0.857	0.490	0.408
TOTAL		11	11	0						Chi-square =	1.500	1.800
											p=0.22	

[a] $E(d_{1j}) = d_j r_{1j}/r_j$ (Pollock et al. 1989)
[b] $var_1(d_{1j}) = d_j r_{01}(r_j - d_j)/r^2(r_j - 1)$ (Pollock et al. 1989)
[c] $var_2(d_{1j}) = r_{0j} r_{1j} d_j / r_j^2$ (Pollock et al. 1989)

Appendix D. Survival statistics of orphaned bears released in the Great Smoky Mountains.

Table D.1. Minimum survival of days postrelease for rehabilitated orphan bears released into the Smoky Mountains, Tennessee, 1998.

Days Postrelease	No. at risk	No. added	No. censored	No. deaths	Survival	Mortality	Variance (survival)	90% CI Lower	90% CI Upper
0-15	0	11	1	0	1.0000	0.0000	0.0000	1.0000	1.0000
16-30	10	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
31-45	10	0	0	0	1.0000	0.0000	0.0000	1.0000	1.0000
46-60	10	0	1	1	0.9000	0.1000	0.0081	0.7520	1.0000
61-75	8	0	1	0	0.9000	0.0000	0.0101	0.7345	1.0000
76-90	7	0	0	0	0.9000	0.0000	0.0116	0.7230	1.0000
91-105	7	0	0	0	0.9000	0.0000	0.0116	0.7230	1.0000
106-120	7	0	0	0	0.9000	0.0000	0.0116	0.7230	1.0000
121-135	7	0	2	1	0.7714	0.1429	0.0194	0.5421	1.0000
136-150	4	0	1	0	0.7714	0.0000	0.0340	0.4681	1.0000
151-165	3	0	1	0	0.7714	0.0000	0.0453	0.4212	1.0000
166-180	2	0	2	0	0.7714	0.0000	0.0680	0.3424	1.0000
TOTAL		**11**	**9**	**2**					

Table D.2. Maximum survival of days postrelease for rehabilitated orphan bears released into the Smoky Mountains, Tennessee, 1998.

Days Postrelease	No. at risk	No. added	No. censored	No. deaths	Survival	Mortality	Variance (survival)	90% CI Lower	90% CI Upper
0-15	0	11	1	0	1.0000	0.0000	0.0000	0.7616	1.0000
16-30	10	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000
31-45	10	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000
46-60	10	0	2	0	1.0000	0.0000	0.0000	0.7616	1.0000
61-75	8	0	1	0	1.0000	0.0000	0.0000	0.7616	1.0000
76-90	7	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000
91-105	7	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000
106-120	7	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000
121-135	7	0	3	0	1.0000	0.0000	0.0000	0.7616	1.0000
136-150	4	0	1	0	1.0000	0.0000	0.0000	0.7616	1.0000
151-165	3	0	1	0	1.0000	0.0000	0.0000	0.7616	1.0000
166-180	2	0	0	0	1.0000	0.0000	0.0000	0.7616	1.0000
TOTAL		**11**	**11**	**0**					

VITA

Jay Edwin Clark was born in Bowling Green, Kentucky on 16 April 1974. He graduated from Franklin County High School in Winchester, Tennessee in 1992. He then attended Maryville College in Maryville, Tennessee for 2 years before transferring to the University of Tennessee, Knoxville (UTK) in the summer of 1994. Jay received his Bachelor of Science degree in Wildlife and Fisheries Science in December, 1996 and began his Master's research on nuisance black bears in January, 1997. He received his Master's of Science degree in Wildlife and Fisheries Science at UTK in August, 1999. Jay resides in Stillwater, Oklahoma where he is currently working on his Ph.D. in Wildlife Ecology.